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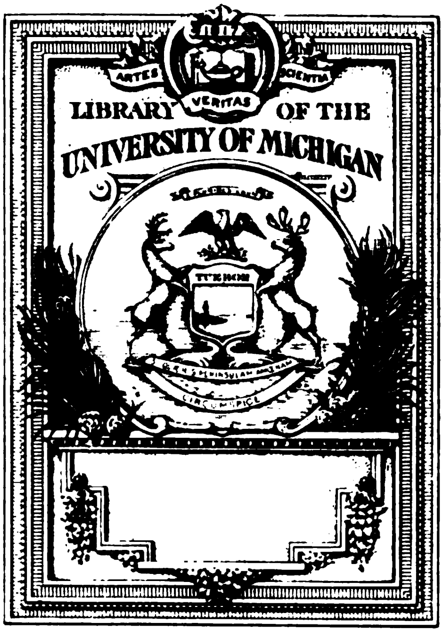

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JUNE, 1920 BULLETIN 219

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# ECCENTRIC GROWTH AND THE FORMATION OF REDWOOD IN THE MAIN STEM OF CONIFERS

By GEORGE P. BURNS

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General

# BULLETIN 219: ECCENTRIC GROWTH AND THE FORMATION OF REDWOOD IN THE MAIN STEM OF CONIFERS

By George P. Burns

The factors which cause the production of eccentric growth and the formation of redwood in coniferous trees have been the basis for many field observations and a small amount of experimental work. These phenomena have been generally explained as being due to either one or more of the following causes:

(1) The wind which acts as a mechanical stimulus resulting in a compression on the leeward and a tension on the windward side, the tree forming its greatest growth and redwood on the compression side.

(2) Differences in the illumination on the north and south sides.

(3) Differences in the branching and, hence, better nutrition on the branched side.

(4) Gravity acting as a stimulus.

The literature on this subject has been carefully compiled and discussed by Grossenbacher (3). Reference to that work makes such a discussion unnecessary in this bulletin. Only those articles which deal with the experimental phases of the subject will be mentioned.

The conditions under which trees grow in the field are so varied that it seems impossible from field observations to determine which one of the many environmental factors is the causal factor leading to the formation of redwood and eccentric growth. Thus, for example, cases have been cited of leaning trees which have produced redwood on the lower side and it has been assumed that its formation was due to the compression exerted, or supposed to be exerted, on that side, regardless of the fact that gravity had exerted a one-sided effect.

Again redwood formation is often attributed to compression which in turn is ascribed to the continued effect of strong prevailing winds. But it is true that trees in such regions often lean with the wind. Hence the redwood formation may be due either to compression or to the one-sided effect of gravity. One cannot dogmatically assert the causal factor or factors in such cases unless the assertion is predicated on carefully controlled experimental trials. Furthermore, not all such trials are beyond criticism. For example, Cieslar (1) so bent young spruce trees that the upper part of the stem lay in a horizontal position, but he failed to consider the one-sided effect of gravity. Trials by some other workers are open to similar objections.

Hartig (4) has investigated this subject more fully than has any other worker. His early work, based on trees cut from forests, led him to conclude that longitudinal pressure on the cambium caused redwood production and that wind caused longitudinal pressure. He attempted to correlate eccentric growth of trees on edges of forests, mountain slopes, etc., with the direction of the prevailing winds and attributed these phenomena wholly to a compression stimulus. Further studies (5) led him to state that gravity acting as a stimulus may also cause the production of redwood and eccentric growth and to say that both compression and gravity cause exactly the same reaction in trees.

Ewart and Mason-Jones (2) bent lateral branches and main axes of *Cupressus nutkaensis, C. Lawsoniana, Pinus contorta* and *P. Cembra* and concluded that the formation of redwood is a morphogenic response to a gravitational stimulus which may be modified or suppressed by very strong pressure stimuli. The stimulus "is able to spread longitudinally from the region where it is directly perceived."

Pennington (7) as a result of much careful experimentation found that there was no increase in the amount or kind of mechanical tissue under the influence of longitudinal compression in the four woody stems with which he worked. He states that a review of the literature on stimulation effects of compression fails to show that compression as such has a stimulating effect and that the term "is loosely applied or evidently connected with other causes of stimulation."

The experiments reported in this bulletin were directed chiefly at the proposition stated by Hartig that both gravity and wind are causal factors in the production of redwood. Some data will be presented tending to show that neither light nor one-sided branching are direct factors in its production.

A series of experiments was started in the open on the white pine, *Pinus strobus*. Trees 2 to 3 meters high were bent at various angles. A stake was driven firmly into the ground from 2 to 2.5 meters from the base of each tree and the tree was wired at the desired angle. In order to lessen the likelihood of injury a sling of rubber hose was passed around the stem and the wire attached to it. That the trees were under a constant mechanical strain throughout the entire experimental period of from two to four years was shown by the fact that when the wires were cut the trees sprang upward, although of course they never attained their original perpendicular positions.

Cross sections of trees grown in these positions showed remarkable eccentric growth and a large amount of redwood on the lower (compression) side. Plate I shows six discs taken from such a tree, the largest ones near the base, the smallest just below the sling. Some of the sections are more nearly triangular than round due to the enormous radial growth on the under side. The section made near the base which was only slightly out of the perpendicular was more nearly round. The more triangular discs were cut from the part of the stem which was in a more nearly horizontal position. No attempt was made to determine accurately the amount of strain in the different regions nor to measure the angle at which the stem was growing, although it is possible, had this been done, that interesting data might have been secured.

One tree which was bent over during two growing seasons was essentially concentric when the experiment was started. In 1912 its first year under strain it produced 165 rows of cells on the lower (compression) side and only 25 rows on the upper (tension) side. As Hartig has said these two kinds of wood differed greatly in structure. The cell walls were thick with characteristic thickenings as is shown in his figures 10 and 11. The cells were not arranged in the definite rows so characteristic of coniferous wood but were rounded with intercellular spaces and without definite arrangement. There is considerable variation in the structure and Hartig's illustration represents an extreme case. The wood on the upper (tension) side closely resembled normal wood.

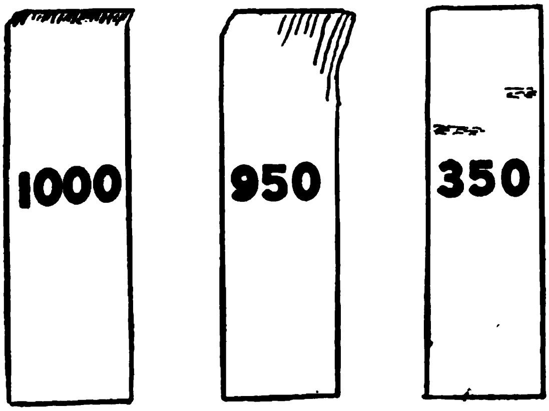


**FIG. 1. Diagrams of blocks of white pine wood which had been tested for compression strength. The redwood failed at 1000 and 950 lbs., respectively; the whitewood at 350 lbs.**

Mechanical tests showed remarkable differences between the red- and normal woods. All mechanical tests were made with white pine as it was the only wood available in sufficient size. Sections were sawed into blocks 1 x 1½ x 5 cm. and tested at the College of Engineering. Figure 1 shows three of the many blocks submitted to pressure. These blocks failed or "buckled" at 1000 and 950 pounds in the case of redwood blocks, while the normal wood failed at 350 pounds. A large number of tests indicate that the ratio is approximately 3 to 1. Tests of tensile strength were made on pieces 1 cm. square and 10 cm. long, reduced for testing in the center in the usual way. These showed that the tensile strength of the redwood was more than twice as great as that of normal wood. The redwood was so hard that these pieces held between the jaws of the machine and broke without reducing the size of the center. It was brittle and broke like glass. Normal wood, on the contrary, mashed and slipped from the machine jaws.

Boards containing redwood and normal wood curve peculiarly in seasoning owing to the varying moisture contents of the two kinds of wood. Samples taken immediately on cutting two trees showed moisture figures as follows: Normal wood 54.2%; redwood 42.3%. Normal wood 48%; redwood 35%.

One of the trees under experiment, after cutting, was seasoned in the botanical laboratory for about three years. It warped in a remarkable manner. It was laid on a piece of paper about three meters long and its outline traced. Four such drawings of this identical tree were made in July and October, 1914, October, 1915, and March, 1917. Its final position in a seasoned condition in March, 1917, nearly three years after cutting is indicated by the dotted lines to the left of the illustration (plate II, figure 1). It was only possible to convince one observer, whose previous experience and technical training entitled him to pass judgment in such matters, that the seasoned tree of the shape shown for 1917 was the same tree from which the original sketch was made, by counting the nodes and noting the stubs.

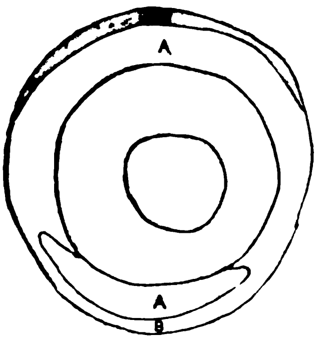
In order to study the seasoning behavior of the two kinds of wood, several samples 55 cm. long were so sawed from a newly cut experimental white pine tree that they contained, some ½, some ⅓ and some ¼ redwood, the remainder of each sample being normal wood. The width of the redwood in each case was 1½ cm. and all samples were perfectly straight when cut from the tree. The ¼ redwood-¾ normal wood sample remained straight after seasoning but the ⅓-⅔ and the ½-½ strips curved sharply as is shown in plate II, figure 2. The extent of the curvature depended upon the percentage of redwood present. Careful measurements indicated that the redwood shortened during seasoning while the length of the normal wood was practically unchanged. The two kinds of wood were then separated, except for a space of about 7 cm. at the base, by a fine rip saw. Instantly the two types of wood assumed the positions shown in plate II, figure 3. At the time of writing, something over a year since these photographs were taken, the redwood in figure 3 curves considerably to the left. Plate II, figure 4 is reproduced from a photograph of the end of the same sample showing more clearly the amount of longitudinal shrinkage. The amount of shrinkage varied considerably in different samples, running from 0.67 to 2.8 percent of the original length. Plate II, figure 5, is reproduced from a photograph of two samples from another white pine tree. The two kinds of wood were ripped apart as shown and "C 1" was seasoned in the laboratory before photographing. It shows the characteristic longitudinal shrinkage of the redwood. "C 3" was placed in tap water immediately after cutting from the tree and photographed after several days. The plate shows the rather remarkable fact that the redwood became elongated, becoming longer than the adjacent normal wood. "C 1" was later placed in tap water and its redwood strip increased in length until it exceeded that of the normal wood, resembling "C 3."

In 1911 a large white pine tree which leaned slightly to the north was cut down and sawed into planks 5 cm. thick and 1 meter long in such a manner that each plank represented a strip of wood extending through the tree from north to south. Each plank was then cut into strips 5 cm. wide. Every strip was straight when it was brought into the laboratory. Every one of these strips today, nine years after the sawing, is straight, except those representing the north (lower) side which contained redwood. These strips are warped owing to the shortening of the redwood in a manner similar to that illustrated in the experimental trees. The percentage of shrinkage is smaller than that observed in the trial trees and corresponds very closely with that given by Hartig. The difference is probably due to the angle at which the tree leaned. It is a question how much compression was exerted on the cambium of this tree which had a diameter of over a meter.

The curving of the redwood is a phenomenon well known to mill men who run circular saws. If a log is so placed that the saw separates the redwood from the normal wood the former's shortening and curving as shown in plate II, figure 3, binds the saw and stops the mill. In such cases it is often necessary to chop out the saw. Accordingly they so saw the log that the redwood will be on one side of the timber. If there is a large percentage present the timber warps when seasoned as is shown in plate II, figure 2, or if the percentage of normal wood is too great the redwood cells may be pulled asunder, as recently reported by Koehler (6), thus materially weakening the timber.

It is at once apparent that a thorough knowledge of the behavior of redwood and its recognition is vitally important to manufacturers of such goods as sounding boards or air-ship propellers and to all industries which need must use a homogeneous wood.

The discs from the experimental trees under consideration up to this point were all taken below the sling to which the bending wire was attached and hence were under a considerable compression on the lower side. Above the sling, however, they were subjected to no such strain, the compression of the lower side and tension of the upper side being due only to the weight of the top. This part of the tree owing to gravity later became erect. A cross section through this portion is shown in figure 2. The leader was two years old when the experiment was started. The wood of the third ring was formed under experimental conditions. This shows that on the under side the tree produced 60 rows of cells of redwood and, later, 12 rows of whitewood; on the upper side it produced 40 rows of cells of whitewood and, then, 20 rows of redwood. A section below the sling showed 130 rows of redwood on the lower side and 27 rows of whitewood on the upper side. The first section demonstrates the fact that whatever the cause for redwood production on the lower side it did not last through the growing season. The same holds true for the upper side which formed whitewood during part of the season and then began producing redwood. The explanation of this phenomenon lies in the fact that when it erected itself in response to the stimulus of gravity it did not stop in a perpendicular position but went beyond so that during the later part of the growing season the conditions were reversed and the former upper side was later actually the lower side. In this position redwood was produced. Many examples of this kind were found in the work later conducted in the laboratory. This is undoubtedly the explanation to be given to figures 34 and 35 of Hartig in which a lateral branch bends up to replace a lost terminal branch and shows redwood on the original upper side. Hartig said that the branches produced redwood



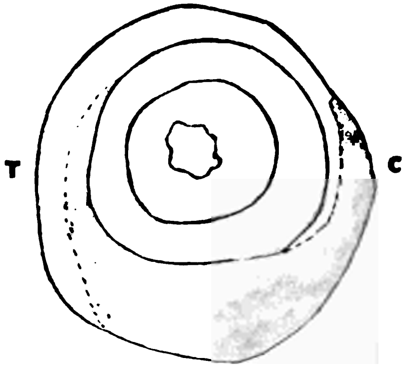


**FIG. 2.** Drawing of a cross section of the 3-year old leader of leaning white pine tree cut above the sling, showing that the tree produced both redwood and normal wood on the same side during one growing season. "A" represents wood produced during the first part of the season; "B," that produced in late summer. Camera lucida drawing.

**FIG. 3.** Cross section of white pine stem which was bent at right angles to gravity. "T" represents the side under tension; "C," that under compression. Camera lucida drawing.

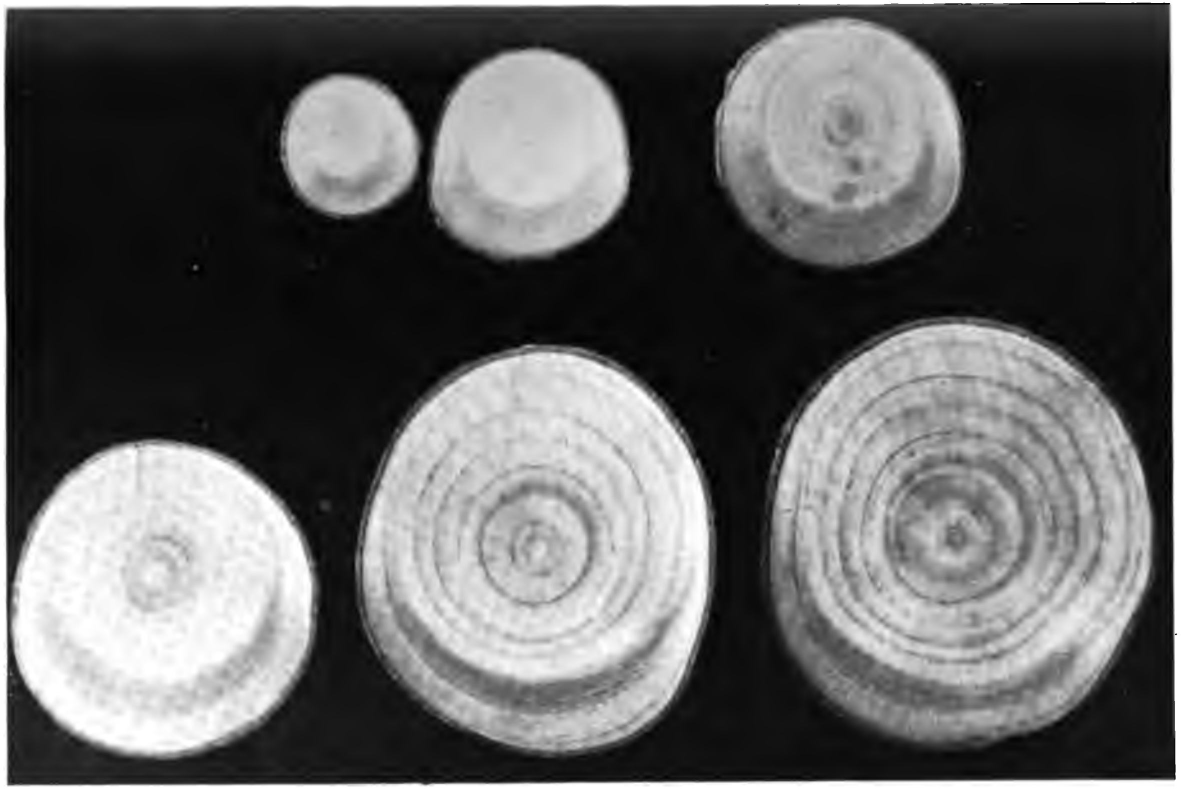


PLATE I

Photograph of sections through the stem of a white pine tree which had been fastened in a leaning position. The greatest growth and redwood formation were found on the lower side.

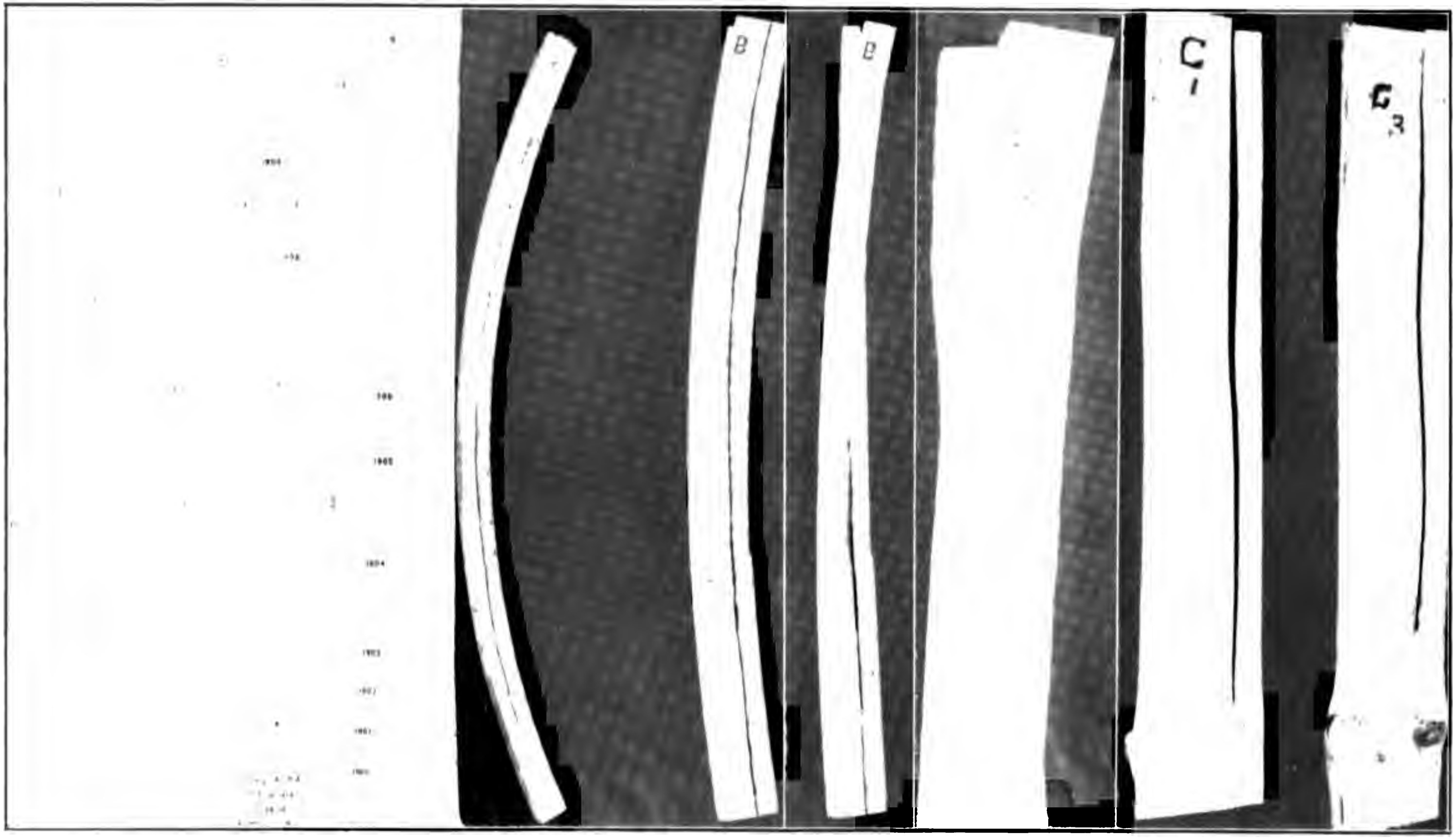


PLATE II

Photographs showing the longitudinal shrinkage of redwood during seasoning. (Note explanation in text page 6.)

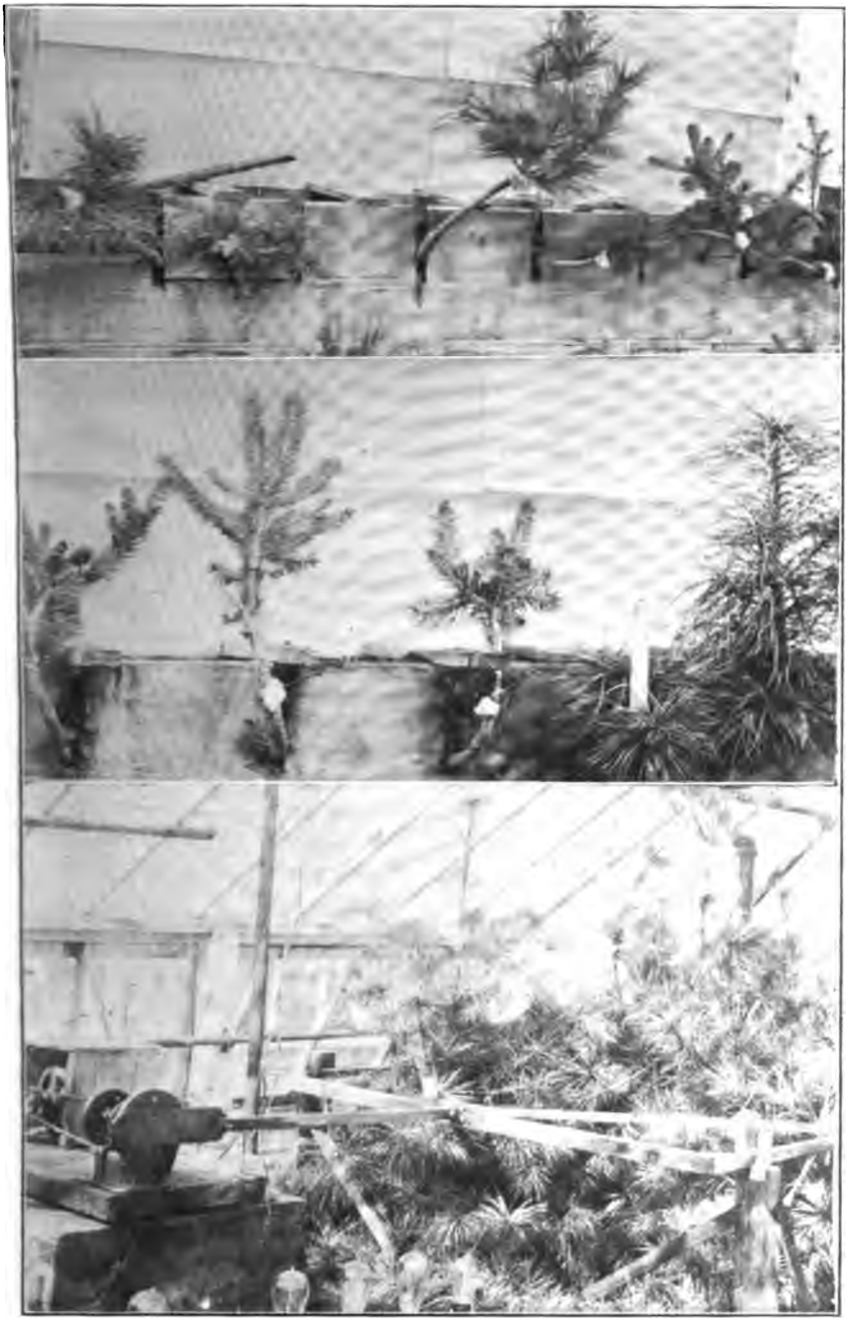


PLATE III

FIG. 1. Trees bent at right angles to force of gravity. Mechanical strains were on the sides.

FIG. 2. Trees bent to produce compression on the upper and tension on the lower side.

FIG. 3. Apparatus used to produce an "artificial wind."

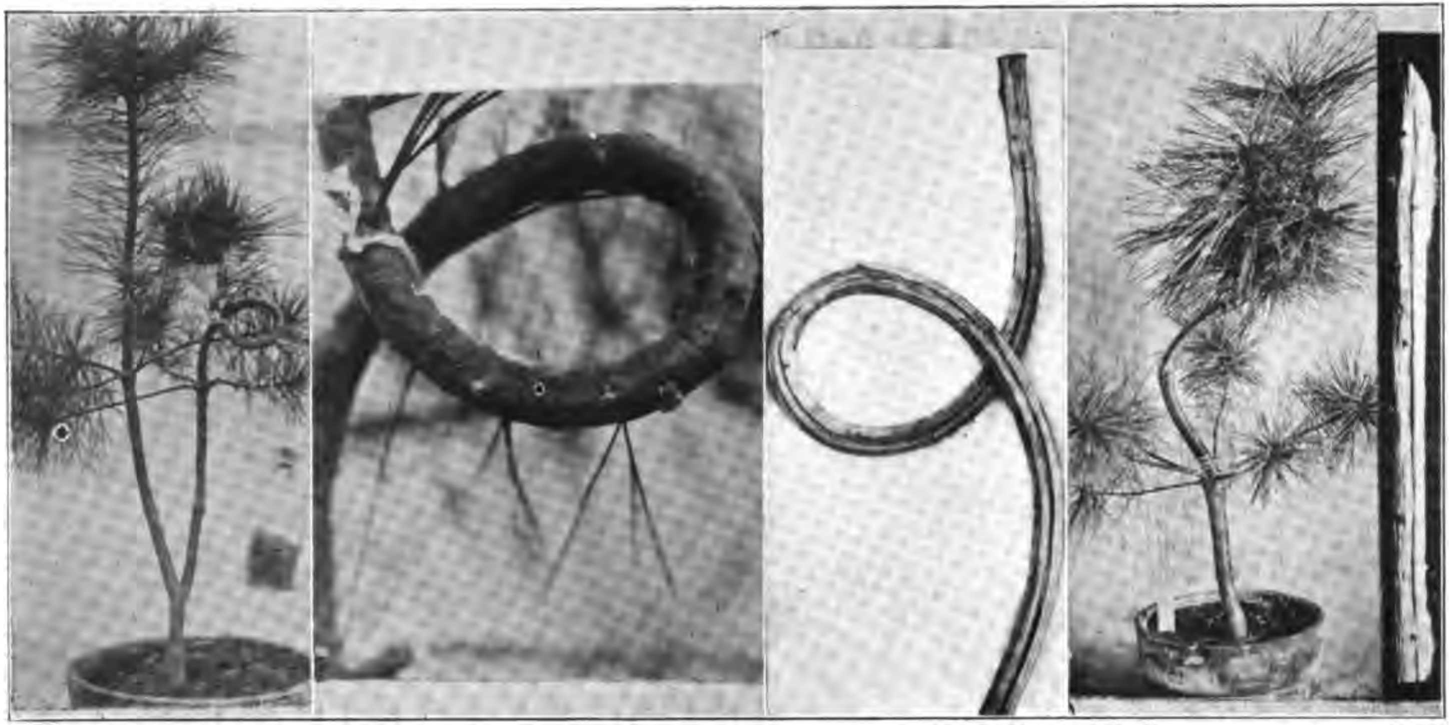


PLATE IV

FIGS. 1 and 2. Leader of white pine tied in circle and allowed to grow one season.
FIG. 3. Longitudinal section of stem shown in fig. 2. Note redwood on the lower side.
FIG. 4. White pine fastened to a bent wire and bow exposed to the south.
FIG. 5. Leader of white pine bent by motor. Note ridge of wood on the side which was at right angles to the bending force.

on the under side as a result of gravity stimulus and redwood on the upper side as a result of a compression stimulus.

In the open field, as has been said, compression and gravity usually work together. Trees located on a mountain or on the edges of forests tend to lean rather than to grow erect and the literature does not seem carefully to set forth this fact. On the contrary it is quite possible so to grow trees under experimental (greenhouse) conditions that compression and gravity do not work together; and they were so grown in the trials now under consideration. Pine and spruce, *Picea excelsa,* were grown in pots and, when about 80 cm. high, the more thrifty were subjected to the following procedure. They were so placed and fastened:

(1) That the top and bottom of the stems were approximately neutral, whereas the sides were under tension and compression.

(2) That the lower side was under tension and the upper under compression.

(3) That neither top nor bottom were under any material strain.

(4) That there were no strains and no top or bottom.

The first three situations were secured by use of several long boxes containing soil, with slits on one side in order to provide an opening for the tree stems, the trees being transplanted into them in a horizontal position, the box tops being left open for watering. For example, the trees in one box were bent at right angles to the force of gravity by means of a cord passed over a pulley and weighted with a bottle of shot. In this position the wood on one side was compressed, that of the other side stretched and the bottom and top were approximately neutral (plate III, figure 1).

The trees for the most part did not remain in a horizontal position but, due to the geotropic response, tended to become erect. In every case there was a marked development of redwood and eccentric growth on the lower side. Neither the compression nor the tension side showed any response in most trees although in one case a section of white pine taken 15 cm. from the box showed an extension of the redwood along both sides. The basal section of the same tree had redwood only on the bottom. The peculiar distribution of the redwood in figure 4 is evidently due to the twisting of the stems caused by the combination of the forces produced by the weight of the shot and the geotropic stimulus. This experiment taken alone would not be very conclusive but the distribution of growth will be understood when studied in connection with results recorded later.

A similar set was arranged and the trees pulled directly upward so that the upper side was compressed and the lower was under a high tension (plate III, figure 2). In this case the force due to the weight of the shot worked in the same direction as the force of gravity and the trees soon became erect above the place of attachment of the wire. In every case there was a marked development of redwood on the tension side which in this case was the lower side. Figure 4 is a diagram of a cross section of one of these trees. The inner line shows that the tree was almost concentric at the beginning of the ex-

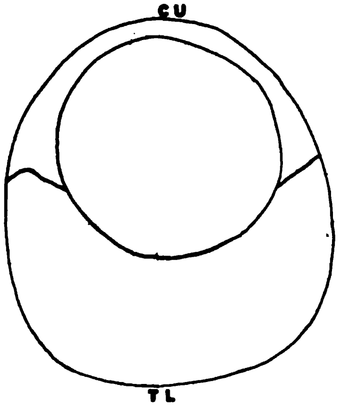


FIG. 4. Drawing of cross section of a white pine tree so grown that the upper side "C U" was under compression and the lower side "T L" was under tension. Camera lucida drawing.

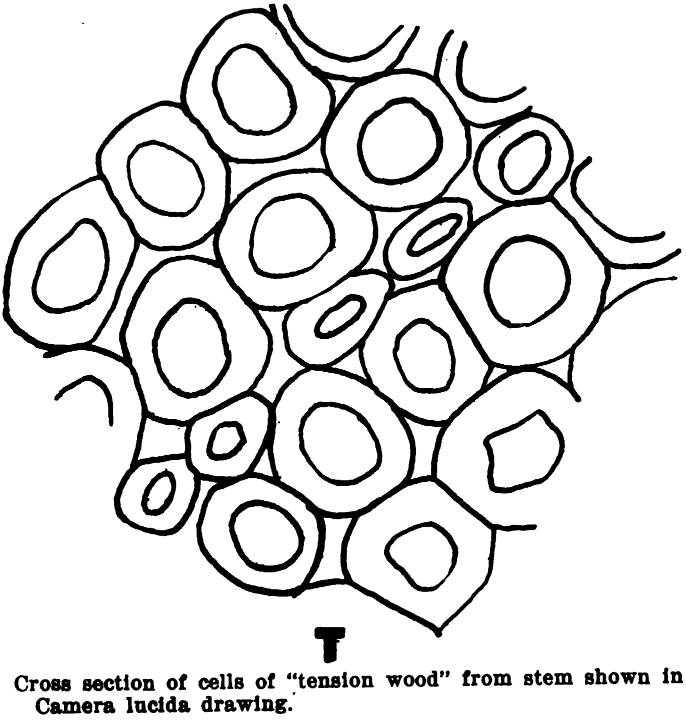
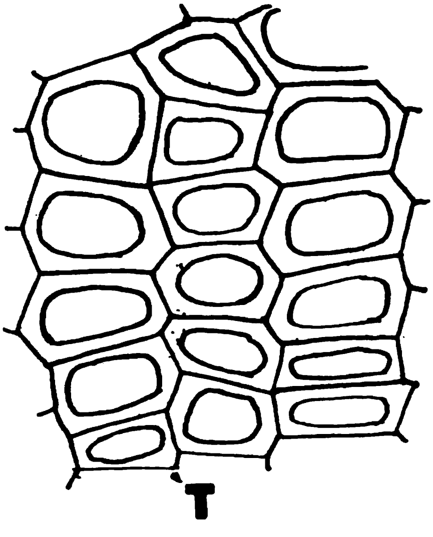


FIG. 5. Cross section of cells of "tension wood" from stem shown in fig. 4. Camera lucida drawing.

periment. The outer line shows the amount of radial growth which took place during the experiment. This eccentricity is strongly marked. On the lower side which was under tension the tree produced 210 rows of cells of typical redwood, on the upper (compression) side, 63 rows of apparently normal wood. No attempt is made in figure 5 to show the nature of the thickening of the cell walls of this "tension wood" from the lower side of the stem. This drawing resembles the drawing of compression wood given by Hartig. It shows that the tracheids are rounded and thick walled and that between them many irregular spaces are found. Figure 6 is a drawing of "tension wood" from the upper side of a leaning tree. The regularity of the cells and the absence of intercellular spaces is to be noted as well as the apparent normality of the wood structure.



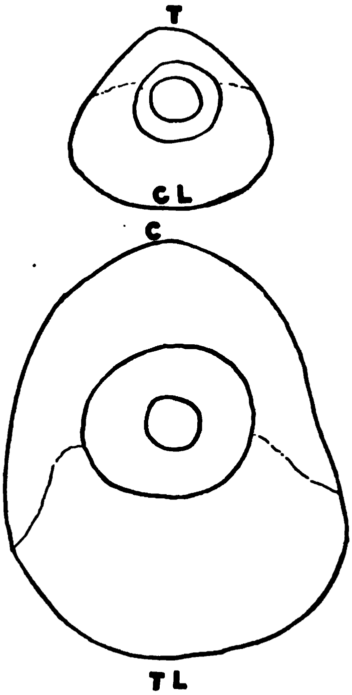


**Fig. 6.** Drawing of cells of "tension wood" from the upper side of a leaning tree. Compare with drawing of "tension wood" shown in fig. 5. Camera lucida drawing.

**Fig. 7.** Drawings of sections from an S-shaped tree. The larger section shows redwood and greatest radial growth on the lower-tension, "T L," side, while the smaller shows the same phenomena on the lower-compression "C L" side. Camera lucida drawing.

Another set of somewhat taller trees were arranged in a similar manner and a small bottle of shot tied to the end of the leader of each tree to prevent it from erecting itself in response to gravity. The weight was heavy enough to bend the top down and the tree became S-shaped. From the box to the sling the upper side was under compression, while from the sling to the top the lower side was under compression. In this position redwood was developed only on the under side regardless of the two strains. The two diagrams in figure 7 show the arrangement of the redwood. The larger section was taken near the base where the trunk was bent upward and the lower side was accordingly under tension. It developed 205 rows of redwood cells while the upper side under compression produced 136 rows of cells of normal wood. The tree in the region of the smaller section also developed a much larger percentage of wood on the under side, which was under compression in this case.

Table I shows the number of rows of cells formed in relation to mechanical strains and position of the stem with reference to gravity. The greater number of cells was always found on the lower side.

| Tree number | I | II | III | IV | V |
|---|---|---|---|---|---|
| Under side (tension) ........... | 53 | 142 | 125 | 225 | 205 |
| Upper side (compression) ....... | 27 | 43 | 63 | 112 | 136 |
| Under side (compression) ....... | 15 | 108 | 130 | 165 | 162 |
| Upper side (tension) ............ | 6 | 16 | 27 | 25 | 28 |

The end of a rapidly growing white pine was turned to form a circle and held by a pulley as shown in plate IV, figure 1. Figure 2 of the same plate shows the wrinkles in the cortex indicating that the inner side was strongly compressed. A string held the loop from spreading, the stem being protected from injury with cotton batting. The outer side of the circle was of course under tension. Figure 3 of this plate represents a longitudinal section of the stem after seasoning. This shows conclusively that eccentric growth and development of redwood are not the result of compression, for both occur on the lower side regardless of nature of the strain. The only place in the loop which was practically erect was almost concentric. This result would seem to show that the suggestion of Ewart and Mason-Jones "that very strong pressure applied to a feebly active cambium may overcome the gravitational influences normally responsible for this special morphogenic response," hardly holds for the white pine.

A number of straight spruce and pine trees which had been growing in pots for three to four years and which were in a thoroughly thrifty condition were laid in a horizontal position on the greenhouse bench early in the spring before growth had started. The stems were supported in order, if possible, to remove all possibility of compression and tension in the sides. The trees were turned by the gardener every 12 hours, one-fourth of a revolution, each tree thus making one complete turn every two days. This procedure was continued with approximate regularity for several months or during the season of radial growth. Figure 8 represents a section through the part of the stem which was two years old when the experiment began. The tree made a good radial growth, almost concentric, and formed a complete ring of redwood. An examination of the entire layer of wood formed during the time of experimentation showed that the cells were not all alike. The spring rows were redwood as were also the outer rows, but there was a narrow, irregular band of much less typical redwood located between these two sets of rows.

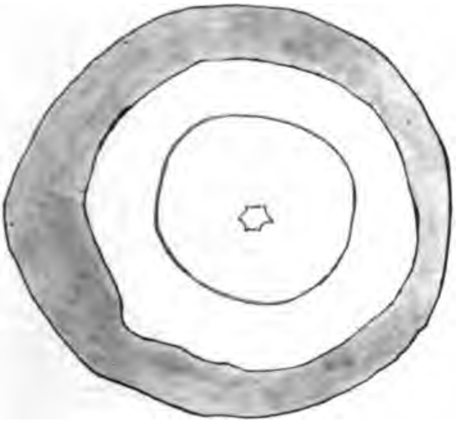


FIG. 8. **Drawing of a cross section of a Norway spruce stem from a tree which was rotated every 12 hours, one-fourth of a revolution. (Redwood shaded.) Camera lucida drawing.**

A number of trees were fastened with raffia to a bent wire (plate IV, figure 4). These were then so placed on the bench that the bends were exposed, some to the north, some to the south, some to the east and some to the west. An examination of these trees failed to show any reaction which could be correlated to the exposure of the stem, all producing redwood on the lower sides regardless of exposure or mechanical strains.

An attempt was made to determine whether or not mechanical strains could cause the white pine to produce redwood. A large number of white pines were transplanted to the greenhouse bench. After a period of two years when they had become firmly established and were growing rapidly, they were fastened to a frame in such a way that they could be moved continuously in one plane by means of an electric motor. The frame moved back and forth a distance of 25 cm. The trees were so fastened that one set was moved back and forth, giving alternate tension and compression; a second set was moved forward, only giving compression on one side, with tension on the other; a third set was not attached to the frame but pushed gently backwards and then allowed to sway much as they would when struck by the wind. The motor was run throughout the active season of radial growth—except for a few minor accidents which caused very slight interruption; then, in the late summer, the trees were marked and sectioned. In no case did redwood formation nor marked eccentric growth take place, although the trees produced many rows of cells. It was impossible to correlate the growth with the "artificial wind."

In several cases the cord from the frame was attached near the end of the long slender leader. The lower part of the stem was so rigid that the slender leader made a very sharp bend above the last whorl of branches, indeed so sharp a bend that it seemed as if the leader must break. Before the season ended it was apparent that the stem was flattened at right angles to the force causing the bend. When the bark was removed a definite ridge of wood was found on each side of the stem at right angles to the compression and tension sides (plate IV, figure 5). The ring of wood on the sides of the stem on which the strains were exerted was 45 cell-rows wide, while at right angles to these through the ridge it was 83 cell-rows wide (figure 9). Neither on the ridges, the place of greatest radial growth, nor on the sides where mechanical strains were greatest was any redwood whatsoever developed. No detailed anatomical study of the cell structure was made; however sections were examined to determine the nature of the cells forming the ridges. The wood lacked all characteristics of

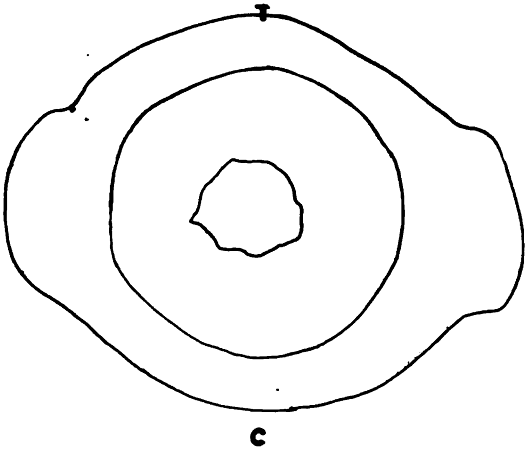


FIG. 9. Drawing of a cross section of the leader of a white pine stem which shows marked increase in radial growth on the sides at right angles to tension "T" and compression "C" strains. Camera lucida drawing.

redwood. Very little reduction in the size of the summer wood cells was noted. The entire ring was practically homogenous. Sections at right angles to the ridges and in the areas of mechanical strains showed that in the spring the cells were of normal size, shape and thickness. There was some differentiation in the summer wood, the last one-third of the ring was somewhat irregular and the cells were a little smaller (figure 10).

This trial seems to indicate that the production of summer wood may be due to the pressure of the mechanical forces. On the ridges where the pressure of the bark was certainly much reduced there was no differentiation into spring and summer wood, while on the side under the mechanical strain there was a tendency to form smaller cells.

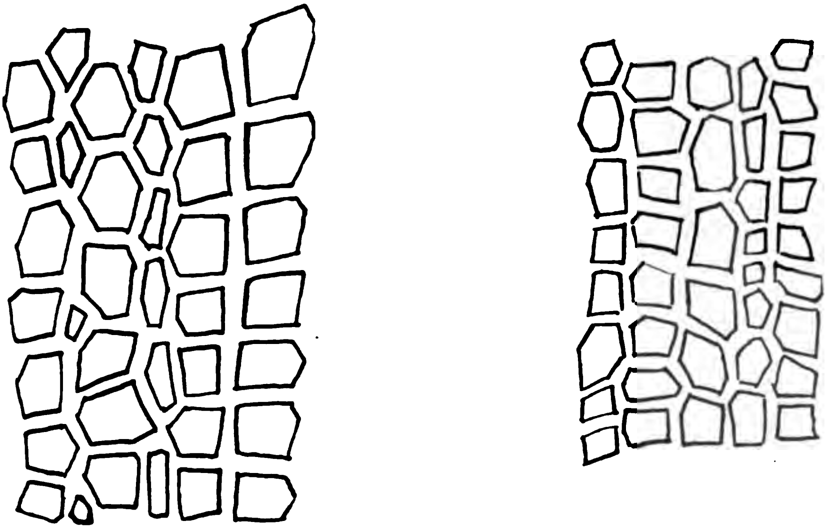


**FIG. 10.** Drawings of cross sections of cells formed on the compression side of the leader shown in fig. 9. The drawing on the left was made from cells formed in the spring; that on the right from those formed in the summer. Camera lucida drawing.

This line of experimentation may throw some light upon the much mooted question of the cause of the production of summer wood. It also shows that eccentric growth is not necessarily associated with the formation of redwood.

A number of fir trees, *Abies balsamea,* growing near the timber line on Mount Mansfield (approximately 4,200 feet above sea level, 44.5° N. lat.), were examined in the summer of 1919. These trees were stunted, were from two to three meters high and had been long subjected to west and northwest winds of high velocity. The windward sides of the top were branchless, the leeward side closely branched and heavily leaved. Cross sections of these stems were practically concentric. These trees grow very slowly and on this account are unsatisfactory material for this study.

A number of trees of pitch pine, *Pinus rigida,* growing in the open were so trimmed that the branches were left only on about 120 degrees of the circumference. After two to four years these were cut and examined. They showed no correlation between the width of the rings and the method of trimming. Whatever the factor causing eccentric growth it evidently is not the method of trimming and is not dependent upon the place of food supply from the leaves.

That the cambium may be caused to divide more rapidly by other stimuli than that of gravity is evident from a study of the literature reviewed by Grossenbacher. One striking example was found in a very old sycamore tree, *Platanus occidentalis.* This large tree grew near the shipyards of the Champlain Transportation Company at Shelburne, Vt. These yards have been used continuously for ship building and repairs for fully a hundred years. The trunk of the tree exhibited numerous wart-like projections of various sizes on its surface. One was at a loss to explain the matter until a large spike was found extending from the center of one of these warts. By use of an axe it was soon determined that a spike was buried in each projection. In this case there was evidently a traumatropic response.

## SUMMARY

1. Redwood and eccentric growth usually but not necessarily occur together.
2. Compression does not act as a stimulus causing the cambium to divide more rapidly and produce redwood.
3. Pressure may be a factor in the differentiation of the annual ring into spring- and summer-wood, even in the white pine and spruce where normally such differentiation is not especially marked.
4. The production of redwood in the trees examined in these experiments seemed to be a morphogenic response to gravitation stimulus.

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JANUARY, 1921 BULLETIN 220

## University of Vermont and State Agricultural College

# Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# COMMERICAL FERTILIZERS COMMERCIAL FEEDING STUFFS AGRICULTURAL SEED

## (INSPECTION BULLETIN)

BURLINGTON
FREE PRESS PRINTING COMPANY
1921

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# BULLETIN 220: CONCERNING FERTILIZERS, COMMERCIAL FEEDING STUFFS, AGRICULTURAL SEED

By J. L. Hills, C. H. Jones, G. F. Anderson, Anna S. Lutman

The results of the police work performed during 1920 by the Station in accordance with state laws is set forth in condensed form in this bulletin. The Station regrets its inability to furnish the full information which has been vouchsafed prior to 1919.

It may be said in brief:

*Fertilizer Control.* That the fertilizers sold in 1920, as a whole, were quite as good as they were represented to be.—Pages 3-15..

*Feeding Stuffs Inspection.* That the results were normal, only a few brands being deficient and only two seriously so.—Pages 15-23.

*Agricultural Seed Inspection.* That one lot in seven was not guaranteed; that one in five was deficient and one in 14 seriously deficient in respect to the maintenance of the purity guaranty; and that a very large proportion were of low viability.—Pages 23-32.

## FERTILIZER CONTROL

The sampling agents of the Station visited a large number of Vermont cities, towns, villages and farms in the spring and early summer of 1920, and drew 246 samples from dealers' stocks representing 126 of the 169 brands of commercial fertilizers licensed for sale by the following companies:

| Licensees | Licensed brands | Brands sampled |
|---|---|---|
| American Agricultural Chemical Co. | 53 | 39 |
| Armour Fertilizer Works | 7 | 7 |
| Atlantic Packing Co. | 4 | 3 |
| Bowker Fertilizer Co. | 9 | 7 |
| Burlington Rendering Co. | 5 | 5 |
| Coe-Mortimer Co. | 8 | 8 |
| Columbia Guano Co. | 8 | 5 |
| Essex Fertilizer Co. | 6 | 6 |
| International Agricultural Corporation, Buffalo Fertilizer Works | 8 | 4 |
| International Products Co. | 1 | 0 |
| Listers' Agricultural Chemical Works | 10 | 8 |
| Lowell Fertilizer Co. | 8 | 8 |
| National Fertilizer Co. | 5 | 0 |
| New England Fertilizer Co. | 5 | 5 |
| Parmenter & Polsey Fertilizer Co. | 4 | 4 |
| Providence Farmers' Exchange | 2 | 2 |
| Reading Bone Fertilizer Co. | 7 | 6 |
| Rogers & Hubbard Co. | 7 | 7 |
| F. S. Royster Guano Co. | 9 | 1 |
| Sanderson Fertilizer and Chemical Co. | 3 | 1 |
|  | 169 | 126 |

No sales were made of 18 brands which were licensed for sale; the entire shipment was used before the sampling agent arrived in 16 instances; and no trace whatsoever could be found of nine brands. As everybody knows, transportation conditions were lamentable during the spring of 1920. Fertilizers arrived late, if at all, and frequently were taken from the car, rushed to the fields and used inside of 48 hours. It was only by dint of great effort that samples of 126 brands were secured, whereas in the years prior to the war, year after year, samples of practically every brand which were licensed were drawn, and fertilizer bulletins that were really worth while were published.

No samples of the following named brands were secured:

American Agricultural Chemical Company's Cereal and Root Fertilizer
American Agricultural Chemical Company's Five-Four-Three Tobacco Fertilizer
American Agricultural Chemical Company's Bradley's Root Crop Manure
American Agricultural Chemical Company's Bradley's Special Potato Manure without Potash
American Agricultural Chemical Company's Bradley's Special XL Superphosphate without Potash
American Agricultural Chemical Company's Darling's Farm Favorite
American Agricultural Chemical Company's Darling's Potato Fertilizer
American Agricultural Chemical Company's Pacific Special Potato Fertilizer without Potash
American Agricultural Chemical Company's Special Soluble Pacific Guano without Potash
American Agricultural Chemical Company's Quinnipiac Phosphate
American Agricultural Chemical Company's Quinnipiac Special Corn Manure without Potash
American Agricultural Chemical Company's Quinnipiac Special Potato Phosphate without Potash
American Agricultural Chemical Company's Williams & Clark's Special Americus Corn Phosphate without Potash
American Agricultural Chemical Company's Williams & Clark's Special Americus Potato Manure without Potash
Atlantic Packing Company's Four-Eight-Four
Bowker Fertilizer Company's Stockbridge Complete
Bowker Fertilizer Company's Stockbridge Market Garden
Columbia Guano Company's Growmore Guano
Columbia Guano Company's Radio Brand
Columbia Guano Company's Victory Brand
International Agricultural Corporation, Inc., Buffalo Fertilizer Works, Farmer's Choice
International Agricultural Corporation, Inc., Bugalo Fertilizer Works, General Favorite
International Agricultural Corporation, Inc., Buffalo Fertilizer Works, Vegetable and Potato
International Agricultural Corporation, Inc., Buffalo Fertilizer Works, Phosphate and Potash
International Products Corporation's Victory Fertilizer
Listers' Agricultural Chemical Works' Eastern Pride Fertilizer
Listers' Agricultural Chemical Works' Excelsior Guano 1916
National Fertilizer Company's Market Garden Fertilizer
National Fertilizer Company's Nitrogen Phosphate Mixture No. 3
National Fertilizer Company's Soluble Bone and Potash
National Fertilizer Company's Universal Phosphate
National Fertilizer Company's XXX Fish and Potash
Reading Bone Fertilizer Company's All Crop Special

**Royster Guano Company's Arrow Head Tobacco Formula**
**Royster Guano Company's Bully Guano**
**Royster Guano Company's Fish and Potash**
**Royster Guano Company's Fish, Flesh and Fowl**
**Royster Guano Company's Landmark Brand**
**Royster Guano Company's Perfecto Tobacco Formula**
**Royster Guano Company's Prime Fish Brand**
**Royster Guano Company's Trucker's Delight**
**Sanderson Fertilizer & Chemical Company's Corn Superphosphate**
**Sanderson Fertilizer & Chemical Company's Phosphate without Potash**

The following condensed statements set forth the essential facts as to the maintenance of guaranties. The order of statement is alphabetical by names of manufacturers.

The first four figures in the table, reading horizontally following the brand name, indicate what the manufacturers' promises were, expressed in percentage terms; and the word following, usually "Yes", less often "No", tells in this laconic, straightforward fashion whether or not the promises have been kept. The remaining words and figures, other than the last two, show the quality of the nitrogen purveyed by the manufacturer. By the use of the words "Passed" or "Not Passed" the character of the organic nitrogen is set forth. The former word is used whenever the analysis indicated a good or passable grade; the latter words when it did not. The next two statements in terms of decimals indicate the proportions of the total nitrogen present in water-soluble and water-insoluble forms. The former includes nitrate nitrogen, ammoniacal nitrogen and such organic nitrogen as is water-soluble; the latter such organic nitrogen as in not soluble in water, more or less of which—more in some cases, less in others—is available to plant growth. The last figure, reading horizontally, indicates in terms of a decimal what proportion of the total phosphoric acid is furnished in available form. The last column shows by the presence of the letter C or S as the case may be whether the potash, if present, was present as muriate or chlorid (C) or as sulphate (S). In case both were present, the letters CS or SC are used, the one first given indicating predominance. The figures in parenthesis, i. e. (23), refer to the matter on page 10 to 12 entitled "Concerning deficiencies."

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Quality organic nitrogen? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | | Water-soluble | Water-insoluble | | |
| **American Agricultural Chemical Company, 92 State St., Boston, Mass.** | | | | | | | | | | |
| A. A. Tobacco Fertilizer | 4.11 | 5 | 4 | 5 | Yes | Passed | .3 | .7 | .9 | S |
| Ammoniated Fertilizer AA | 1.65 | 11 | 10 | .. | Yes | Passed | .6 | .4 | .7 | .. |
| Ammoniated Fertilizer AAA | 2.47 | 11 | 10 | .. | Yes | Passed | .6 | .4 | .8 | .. |
| Bone-Phosphate and Potash | ... | 13 | 12 | 2 | Yes | ...... | .. | .. | .9 | C |
| Complete Potato Mixture | 2.47 | 9 | 8 | 4 | Yes | Passed | .6 | .4 | .9 | C |
| Extra Quality Potato Manure | 4.11 | 11 | 10 | .. | Yes | Passed | .7 | .3 | .9 | .. |
| Grain and Seeding Fertilizer | 1.65 | 11 | 10 | .. | No (1) | Passed | .6 | .4 | .8 | .. |
| Grass and Oats Fertilizer | ... | 13 | 12 | 2 | Yes | ....... | .. | .. | 1.0 | CS |
| Monarch Potato Manure | 3.29 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Grass and Lawn Top Dressing | 4.94 | 7 | 6 | 4 | Yes | Passed | .8 | .2 | .8 | SC |
| Special Vegetable Fertilizer | 3.29 | 11 | 10 | .. | Yes | Passed | .7 | .3 | .9 | .. |
| Universal Phosphate | 0.82 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| *(Bradley Fertilizer Company Brands)* | | | | | | | | | | |
| Alkaline Bone with Potash | ... | 13 | 12 | 2 | Yes | ...... | .. | .. | 1.0 | CS |
| Complete Manure for Top Dressing Grass and Grain | 4.94 | 7 | 6 | 4 | No (2) | Passed | .7 | .3 | .9 | C |
| Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Eclipse Phosphate | 0.82 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Potato Fertilizer | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| Potato Manure | 2.47 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Special Corn Phosphate without Potash | 1.65 | 11 | 10 | .. | Yes | Passed | .5 | .5 | .9 | .. |
| Special Potato Fertilizer without Potash | 1.65 | 11 | 10 | .. | Yes | Passed | .7 | .3 | .9 | .. |
| XL Superphosphate of Lime | 2.47 | 10 | 9 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| *(Crocker Fertilizer and Chemical Company Brands)* | | | | | | | | | | |
| Ammoniated Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .4 | .6 | .8 | C |
| New Rival Ammoniated Superphosphate | 0.82 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .8 | CS |
| Potato, Hop and Tobacco Fertilizer | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| *(Great Eastern Fertilizer Company Brands)* | | | | | | | | | | |
| General | 0.82 | 9 | 8 | 4 | Yes | Passed | .6 | .4 | .9 | C |
| Northern Corn Special | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Potato Manure | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | CS |
| *(Pacific Guano Company Brands)* | | | | | | | | | | |
| Pacific Nobsque Guano | 0.82 | 9 | 8 | 2 | Yes | Passed | .5 | .5 | .9 | C |
| Pacific Potato Special | 1.65 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| Soluble Pacific Guano | 1.65 | 9 | 8 | 2 | Yes | Passed | .5 | .5 | .8 | C |
| *(Quinnipiac Company Brands)* | | | | | | | | | | |
| Corn Manure | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Potato Manure | 2.47 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Potato Phosphate | 1.65 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| *(Read Fertilizer Company Brands)* | | | | | | | | | | |
| Farmers' Friend Superphosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Practical Potato Special Fertilizer | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | CS |

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Quality organic nitrogen? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | | Water-soluble | Water-insoluble | | |
| ***(Williams & Clark Fertilizer Company Brands)*** | | | | | | | | | | |
| Americus Ammoniated Bone Superphosphate | 2.47 | 10 | 9 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Americus Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Americus Potato Manure | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | C |
| Potato Phosphate | 2.47 | 9 | 8 | 4 | No (3) | Passed | .7 | .3 | .9 | C |
| **Armour Fertilizer Works, 1501-1514 Munsey Building, Baltimore, Md.** | | | | | | | | | | |
| Cereal Special No. 1, 2/10/6 | 1.65 | 10.5 | 10 | 6 | Yes | Passed | .6 | .4 | .9 | C |
| Cereal Special No. 2, 2/10/4 | 1.65 | 10.5 | 10 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Four-Ten-Zero Fertilizer | 3.29 | 10.5 | 10 | .. | Yes | Passed | .7 | .3 | .8 | .. |
| Grain Grower 2/8/2 | 1.65 | 8.5 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Phosphate and Potash No. 1, 0/10/2 | ... | 10.5 | 10 | 2 | Yes | ...... | .. | .. | .9 | C |
| Potato, Onion and Vegetable | 3.29 | 8.5 | 8 | 4 | ? (4) | Passed | .6 | .4 | .9 | C |
| Wheat and Clover 0/10/5 | ... | 10.5 | 10 | 5 | Yes | ...... | .. | .. | .9 | C |
| **Atlantic Packing Company, North Ave., Burlington, Vt.** | | | | | | | | | | |
| Three-Eight-Four | 2.46 | 9 | 8 | 4 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Three | 1.65 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Two | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .8 | C |
| **Bowker Fertilizer Company, 43 Chatham St., Boston, Mass.** | | | | | | | | | | |
| All Round Fertilizer | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Corn, Grain and Grass Phosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | CS |
| Four-Ten Hill and Drill | 3.29 | 11 | 10 | .. | Yes | Passed | .8 | .2 | .9 | .. |
| Hill and Drill Phosphate | 2.47 | 10 | 9 | 2 | No (5) | Passed | .7 | .3 | .8 | C |
| Potato and Vegetable Phosphate | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| Superphosphate with Potash | ... | 13 | 12 | 2 | Yes | ...... | .. | .. | .9 | C |
| Sure Crop Phosphate | 0.82 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| **Burlington Rendering Company, North Ave., Burlington, Vt.** | | | | | | | | | | |
| Four-Eight-Four | 3.28 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| One-Ten-One | 0.82 | 11 | 10 | 1 | Yes | Passed | .5 | .5 | .9 | CS |
| Three-Eight-Four | 2.46 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | 1.0 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| **Coe-Mortimer Company, 51 Chambers St., New York, N. Y.** | | | | | | | | | | |
| E. Frank Coe's Columbian Corn and Potato Fertilizer | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| E. Frank Coe's Corn King | 2.47 | 10 | 9 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| E. Frank Coe's Dissolved Phosphate and Potash | ... | 13 | 12 | 2 | Yes | ...... | .. | .. | 1.0 | C |
| E. Frank Coe's New Englander Special | 0.82 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| E. Frank Coe's Original Ammoniated Dissolved Phosphate, 1916 | 1.65 | 11 | 10 | .. | Yes | Passed | .6 | .4 | .8 | .. |
| E. Frank Coe's Prolific Crop Producer | 3.29 | 11 | 10 | .. | Yes | Passed | .8 | .2 | .9 | .. |
| E. Frank Coe's Special Grass Top Dressing Manure | 4.94 | 7 | 6 | 4 | Yes | Passed | .8 | .2 | .9 | C |

### CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| **Brand** | Guaranties |  |  |  | Guaranty met? | Quality organic nitrogen? | Nitrogen |  | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash |  |  | Water-soluble | Water-insoluble |  |  |
| **Columbia Guano Company, Munsey Building, Baltimore, Md.** |  |  |  |  |  |  |  |  |  |  |
| Famous Trucker 4/8/7 | 3.3 | 8.5 | 8 | 7 | No (6) | Passed | .8 | .2 | .8 | C |
| Fish and Potash 2/8/2 | 1.65 | 8.5 | 8 | 3 | Yes | Not passed (7) | .7 | .3 | .9 | C |
| Freedom Guano 4/8/4 | 3.3 | 8.5 | 8 | 4 | No (8) | Passed | .8 | .2 | .9 | C |
| Prize Guano 2/8/5 | 1.65 | 8.5 | 8 | 5 | Yes | Passed | .7 | .3 | .9 | C |
| Soluble Guano 2/8/2 | 1.65 | 8.5 | 8 | 2 | Yes | Not passed (9) | .7 | .3 | .9 | C |
| **Essex Fertilizer Company, 89 North Market St., Boston, Mass.** |  |  |  |  |  |  |  |  |  |  |
| Bone Fertilizer 2/10/0 | 1.64 | 11 | 10 | .. | Yes | Not passed (10) | .6 | .4 | .9 | C |
| Fish Fertilizer 3/8/3 | 2.46 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .8 | C |
| One-Ten-One | 0.82 | 11 | 10 | 1 | Yes | Not passed (11) | .5 | .5 | .9 | C |
| Market Garden 3/8/4 | 2.46 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | ? (12) | Passed | .6 | .4 | .8 | C |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| **International Agricultural Corporation<br>Buffalo Fertilizer Works, 812 Marine Bank Building, Buffalo, N. Y.** |  |  |  |  |  |  |  |  |  |  |
| Buffalo Economy | 1.65 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .8 | C |
| Buffalo High Grade Manure | 3.3 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .8 | C |
| Buffalo New England Special | 1.65 | 11 | 10 | 4 | Yes | Passed | .7 | .3 | .8 | C |
| Buffalo Top Dresser and Starter | 5.8 | 7 | 6 | .. | No (13) | Passed | .7 | .3 | .8 | C |
| **Listers' Agricultural Chemical Works, Lister Ave., Newark, N. J.** |  |  |  |  |  |  |  |  |  |  |
| Corn and Potato Fertilizer | 1.65 | 9 | 8 | 3 | No (14) | Passed | .5 | .5 | .7 | SC |
| Fish and Potash Fertilizer | 2.47 | 11 | 10 | 3 | Yes | Passed | .6 | .4 | .8 | CS |
| Fish Brand Fertilizer | 0.82 | 9 | 8 | 4 | Yes | Passed | .4 | .6 | .8 | C |
| Four-Eight-Four Fertilizer | 3.29 | 9 | 8 | 4 | Yes | Passed | .9 | .1 | .9 | C |
| Grain and Grass Fertilizer Revised | ... | 13 | 12 | 2 | Yes | ...... | .. | .. | .9 | SC |
| King Bee Fertilizer | 1.65 | 11 | 10 | 4 | Yes | Passed | .6 | .4 | .8 | C |
| Squirrel Brand Fertilizer | 0.82 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .8 | CS |
| Success Fertilizer | 1.65 | 9 | 8 | 2 | Yes | Not passed (15) | .5 | .5 | .7 | CS |
| **Lowell Fertilizer Company, 40 North Market St., Boston, Mass.** |  |  |  |  |  |  |  |  |  |  |
| Animal Brand 3/8/4 | 2.46 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Bone Fertilizer 2/8/2 | 1.64 | 9 | 8 | 2 | No (16) | Passed | .6 | .4 | .8 | C |
| Dissolved Bone Fertilizer 2/10/0 | 1.64 | 11 | 10 | .. | Yes | Passed | .6 | .4 | .8 | .. |
| Empress Brand 1/10/1 | 0.82 | 11 | 10 | 1 | Yes | Not passed (17) | .6 | .4 | .9 | C |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .8 | C |
| Three-Eight-Three | 2.46 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .8 | C |
| Three and a half-Ten-Zero | 2.87 | 11 | 10 | .. | No (18) | Passed | .6 | .4 | .7 | .. |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .8 | C |

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| **BRAND** | Guaranties | | | | Guaranty met? | Quality organic nitrogen? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | | Water-soluble | Water-insoluble | | |
| **New England Fertilizer Company, 40A North Market St., Boston, Mass.** | | | | | | | | | | |
| One-Ten-One | 0.82 | 11 | 10 | 1 | Yes | Passed | .6 | .4 | .9 | C |
| Superphosphate 3/8/4 | 2.46 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Three and a half-Ten-Zero | 2.87 | 11 | 10 | .. | Yes | Passed | .6 | .4 | .7 | .. |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | No (19) | Passed | .6 | .4 | .8 | C |
| Two-Ten-Zero | 1.64 | 11 | 10 | .. | Yes | Passed | .6 | .4 | .8 | C |
| **Parmenter & Polsey Fertilizer Company, 41 North Market St., Boston, Mass.** | | | | | | | | | | |
| One-Ten-One | 0.82 | 11 | 10 | 1 | No (20) | Passed | .5 | .5 | .9 | C |
| Plymouth Rock | 2.46 | 9 | 8 | 4 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .8 | C |
| **Providence Farmers' Exchange, 48 Rathburn St., Providence, R. I.** | | | | | | | | | | |
| Corn Fertilizer 2/10/4 | 1.65 | 11 | 10 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Complete Potato 4/8/4 | 3.29 | 8.5 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| **Reading Bone Fertilizer Company, Reading, Pa.** | | | | | | | | | | |
| Dissolved Animal Matter | 0.82 | 11 | 10 | .. | Yes | Passed | .8 | .2 | 1.0 | .. |
| Economy Brand | ... | 11 | 10 | 4 | Yes | ...... | .. | .. | .9 | CS |
| Farmers' Tankage and Potash | 0.82 | 11 | 10 | 2 | Yes | Passed | .8 | .2 | .9 | CS |
| High Grade Truck Food | 3.29 | 13 | 12 | .. | Yes | Passed | .8 | .2 | .8 | .. |
| Reading One-Eight-Five | 0.82 | 9 | 8 | 5 | No (21) | Passed | .7 | .3 | .7 | CS |
| Reading Special Potato and Tobacco Manure | 0.82 | 13 | 12 | .. | Yes | Passed | .6 | .4 | .8 | .. |
| **Rogers & Hubbard Company, Middletown, Conn.** | | | | | | | | | | |
| All Soils—All Crops Phosphate | 3.29 | 9 | 8 | 6 | Yes | Passed | .8 | .2 | .8 | C |
| "Bone Base" Fertilizer for Oats and Top Dressing | 8.22 | 8 | 3 | 4 | Yes | Passed | .9 | .1 | .4 | C |
| "Bone Base" Fertilizer for Seeding Down | 2.47 | 15 | 6 | 4 | Yes | Passed | .3 | .7 | .4 | C |
| "Bone Base" Soluble Corn and General Crops manure | 2.46 | 10 | 8 | 4 | Yes | Passed | .8 | .2 | .7 | C |
| "Bone Base" Soluble Potato Manure | 4.11 | 10 | 8 | 6 | No (22) | Passed | .8 | .2 | .7 | C |
| Complete Phosphate | 0.82 | 9 | 8 | 2 | Yes | Not Passed (23) | .6 | .4 | .8 | C |
| Potato Phosphate | 1.64 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .8 | C |
| **F. S. Royster Guano Company, 1604-1614 Munsey Building, Baltimore, Md.** | | | | | | | | | | |
| Dreadnaught Guano | 1.65 | 8.5 | 8 | 2 | No (24) | Not Passed (24) | .7 | .3 | .9 | C |
| **Sanderson Fertilizer and Chemical Company, New Haven, Conn.** | | | | | | | | | | |
| Atlantic Coast Bone, Fish and Potash | 1.65 | 9 | 8 | 3 | Yes | Passed | .5 | .5 | .8 | C |

## CONCERNING DEFICIENCIES

### AMERICAN AGRICULTURAL CHEMICAL COMPANY

(1) *Grain and Seeding Fertilizer.* Available phosphoric 0.7% short of guaranty, but nitrogen 0.4% above guaranty. Shortage of plant food 3%. Full commercial value probably furnished.

(2) *Bradley's Complete Manure for Top Dressing Grass and Grain.* Nitrogen 0.8% short of guaranty, but available phosphoric acid 0.6% and potash 0.5% above guaranty. No actual shortage of plant food, but full commercial value probably not furnished.

(3) *Williams & Clark's Potato Phosphate.* Potash 0.8% short of guaranty, but nitrogen 0.4% and available phosphoric acid 0.8% above guaranty. No actual shortage of plant food. Full commercial value probably furnished.

### ARMOUR FERTILIZER WORKS

(4) *Potato, Onion and Vegetable* 4/8/4. Nitrogen 0.3% short of guaranty, but available phosphoric acid 0.7% and potash 0.4% above guaranty. No actual shortage of plant food. Full commercial value probably furnished.

### BOWKER FERTILIZER COMPANY

(5) *Four-Ten Hill and Drill.* Nitrogen 0.3% short of guaranty, but available phosphoric acid 0.4% above guaranty. No actual shortage of plant food, but full commercial value not furnished.

### COLUMBIA GUANO COMPANY

(6) *Famous Trucker.* Nitrogen 0.3% short of guaranty, but available phosphoric acid and potash 0.3% above guaranty. No actual shortage of plant food, but full commercial value not furnished.

(7) *Fish and Potash.* Contains 35% of the guaranteed nitrogen and 33% of the total nitrogen found in unavailable forms.

(8) *Freedom Guano.* Nitrogen 0.6% short of guaranty, but available phosphoric acid 0.8% and potash 0.2% above guaranty. No actual shortage of plant food, but full commercial value not furnished.

(9) *Soluble Guano.* Contains 35% of the guaranteed nitrogen and 34% of the total nitrogen found in unavailable forms.

### ESSEX FERTILIZER COMPANY

(10) *Bone Fertilizer* 2/10/0. Contains 37% of the guaranteed nitrogen and 35% of the total nitrogen found in unavailable forms.

(11) *One-Ten-One.* Contains 49% of the guaranteed nitrogen and 47% of the total nitrogen found in unavailable forms.

(12) *Two-Eight-Two.* Available phosphoric acid 0.6% short of guaranty, but nitrogen 0.2% and potash 0.4% above guaranty. No actual shortage of plant food. Full commercial value furnished.

### INTERNATIONAL AGRICULTURAL CORPORATION, BUFFALO FERTILIZER WORKS

(13) *Buffalo Top Dresser and Starter.* Nitrogen 0.5% short of guaranty, but available phosphoric acid 0.7% above guaranty. No actual shortage of plant food, but full commercial value not furnished.

### LISTERS' AGRICULTURAL CHEMICAL WORKS

(14) *Corn and Potato Fertilizer.* Available phosphoric acid 0.5% short of guaranty, but nitrogen 0.3% and potash 0.2% above guaranty. No actual shortage of plant food. Full commercial value probably furnished.

(15) *Success Fertilizer.* Contains 61% of the guaranteed nitrogen and 51% of the total nitrogen found in unavailable forms.

### LOWELL FERTILIZER COMPANY

(16) *Bone Fertilizer* 2/8/2. Available phosphoric acid 0.8% short of guaranty, but nitrogen and potash 0.3% above guaranty. Shortage of plant food 4%. Full commercial value nearly if not quite furnished.

(17) *Empress Brand* 1/10/1. Contains 50% of the guaranteed nitrogen and 43% of the total nitrogen found in unavailable forms.

(18) *Three and a Half-Ten-Zero.* Available phosphoric acid 0.4% short of guaranty. Shortage of plant food 4%. Full commercial value not furnished.

### NEW ENGLAND FERTILIZER COMPANY

(19) *Two-Eight-Two.* Available phosphoric acid 0.8% short of guaranty, but nitrogen and potash 0.4% above guaranty. Shortage of plant food 4%. Full commercial value probably furnished.

### PARMENTER AND POLSEY FERTILIZER COMPANY

(20) *One-Ten-One.* Available phosphoric acid 0.4% short of guaranty, but nitrogen and potash 0.4% above guaranty. No actual shortage of plant food. Full commercial value furnished.

### READING BONE FERTILIZER COMPANY

(21) *One-Eight-Five.* Available phosphoric acid 1.2% short of guaranty, but nitrogen 0.3% and potash 0.5% above guaranty. Shortage of plant food 3%. Full commercial value probably furnished.

### ROGERS & HUBBARD COMPANY

(22) *"Bone Base" Soluble Potato Manure.* Potash 0.6% short of guaranty, but available phosphoric acid 0.2% above guaranty. Shortage of plant food 2%. Full commercial value not furnished.

(23) *Complete Phosphate.* Contains 50% of the guaranteed nitrogen and 45% of the total nitrogen found in unavailable forms.

### ROYSTER GUANO COMPANY

(24) *Dreadnaught Guano.* Available phosphoric acid 0.3% short of guaranty, but potash 0.1% above guaranty. Shortage of plant food 2%. Full commercial value possibly furnished. Contains 35% of the guaranteed nitrogen and 34% of the total nitrogen found in unavailable forms.

## DISCUSSION OF THE RESULTS OF INSPECTION

*Quantity of plant food.* Fertilizers sold in Vermont in the spring of 1920—if one may judge by the results of inspection—as a whole were up to the usual grade. There were 378 guaranties made, 24 of which, or one in 16, were not maintained. Of these 24 deficiencies only 10 or one in 38 were in excess of 0.5%. Twenty-four brands were in trouble, or 19% of the entire number. In 17 of the 24 brands there was no shortage of total plant food, while in the other seven brands the deficiencies in no case were greater than 4%. The manufacturers, as usual, and very properly, furnished very little more plant food than they promised to supply. The average fertilizer sold in Vermont in 1920 was guarantied to contain approximately 2% of nitrogen, 10¾% total and 8¾% available phosphoric acid, and 2½% potash; and it averaged to contain very little more than these figures.

*Quality of plant food.* The information heretofore vouchsafed as to the nitrate and ammoniacal nitrogen contents of the several brands cannot be furnished this year. However, the availability of the organic nitrogen was determined as usual and eight brands were found to contain what seemed to be undue amounts of unavailable organic nitrogen, namely: Columbia Guano Company's Fish and Potash, Soluble Guano; Essex Fertilizer Company's One-Ten-One, Bone Fertilizer; Lowell Fertilizer Company's Empress Brand One-Ten-One; Listers' Agricultural Chemical Works' Success Fertilizer; Rogers & Hubbard Company's Complete Phosphate; Royster Guano Company's Dreadnaught Guano.

The proportions of phosphoric acid furnished in available forms by the several companies vary about as usual. It is gratifying to note the reappearance of potash in considerable quantities.

## CONCERNING THE BRANDS

A study of the brands is interesting. One hundred and sixty-eight were licensed, but only about 25 grades were sold. Speaking broadly, and using ammonia figures in lieu of nitrogen figures for the sake of simplicity, the grades which really seem to have constituted practically all the 1920 Vermont sales, together with the average time prices at which they were sold, were as is shown in the following table.

### NON-NITROGENOUS BRANDS

| Ammonia percent | Available phosphoric acid percent | Potash percent | Brands number | Approximate time price per ton |
|---|---|---|---|---|
| 0 | 10-12 | 2 | 7 | $41 |
| 0 | 10 | 4-5 | 2 | 48 |
| | | NON-NITROGENOUS BRANDS | | |
| 1 | 10-12 | 0 | 2 | $43 |
| 2 | 10 | 0 | 8 | 46 |
| 3 | 10 | 0 | 2 | 50 |
| 3½ | 10 | 0 | 1 | 55 |
| 4 | 10-12 | 0 | 5 | 57 |
| 5 | 10 | 0 | 1 | 66 |
| | | 1% POTASH GOODS | | |
| 1 | 10 | 1 | 5 | $46 |

| Ammonia percent | Available phosphoric acid percent | Potash percent | Brands number | Approximate time price per ton |
|---|---|---|---|---|
| NON-POTASSIC BRANDS | | | | |
| 2% POTASH GOODS | | | | |
| 1 | 8-10 | 2 | 9 | $46 |
| 2 | 8 | 2 | 19 | 51 |
| 3 | 9-10 | 2 | 4 | 59 |
| 3% POTASH GOODS | | | | |
| 2 | 8 | 3 | 17 | $53 |
| 3 | 8 | 3 | 2 | 60 |
| 4% POTASH GOODS | | | | |
| 1 | 8 | 4-5 | 3 | $52 |
| 2 | 8-10 | 4-5 | 5 | 58 |
| 3 | 8 | 4 | 12 | 63 |
| 4 | 8 | 4 | 9 | 70 |
| HIGH POTASH OR HIGH NITROGEN BRANDS | | | | |
| 2 | 10 | 6 | 1 | $63 |
| 3 | 6 | 4 | 1 | 61 |
| 4 | 8 | 6-7 | 2 | 74 |
| 5 | 4 | 5 | 1 | .. |
| 5 | 8 | 6 | 1 | 81 |
| 6 | 6 | 4 | 3 | 80 |
| 7 | 6 | 0 | 1 | 72 |
| 10 | 3 | 4 | 1 | 87½ |

## COST OF COMMERCIAL FERTILIZERS, 1919 AND 1920

A considerable amount of data as to retail prices leads the writer to conclude that the following figures are fairly representative of the time-prices of goods sold in Vermont in 1919 and 1920.

| Ammonia | Available phosphoric acid | Potash | 1919 | 1920 | 1920±1919 |
|---|---|---|---|---|---|
| 1 | 10 | 0 | $36 | $43 | +$7 |
| 2 | 10 | 0 | 43 | 46 | + 3 |
| 3 | 10 | 0 | 50 | 50 | 0 |
| 4 | 10 | 0 | 55 | 57 | + 2 |
| 1 | 10 | 1 | 40 | 46 | + 6 |
| 1 | 8 | 2 | 46 | 46 | 0 |
| 2 | 8 | 2 | 53 | 51 | — 2 |
| 2 | 8 | 3 | 61 | 53 | — 8 |
| 2 | 8 | 4 | 67 | 58 | — 9 |
| 4 | 8 | 4 | 76 | 70 | — 6 |

The increasing inflow and lessened cost of potash has tended to lower the price of goods carrying this ingredient. It seems to have been the policy of the trade to mark up the prices of the lower grades in order to meet the greatly increased costs of manufacture prevailing in the fall, winter and spring of 1919-1920.

Acid phosphate was sold at retail in several parts of Vermont at $32 to $34 and nitrate of soda was offered for about $90. Each contained 16 percent of available plant food or 320 pounds per ton. A pound of available phosphoric acid cost about 10 cts. delivered; a pound of nitrate nitrogen—as good as any and better than many forms found in commercial fertilizers—cost less than 30 cts. delivered. Let us note what nitrogen cost in commercial fertilizers, calculating the available phosphoric acid at the price it was selling for at retail in Vermont in 1919.

1/10 grade 10% = 200 lbs. 200 × $0.10 = $20.
$43 — $20 = $23. 1% ammonia = 0.82% nitrogen = 16.4 lbs. nitrogen for $23 or $1.40 a lb.
2/10 grade 32.8 lbs. nitrogen for $26 or 79.3 cts. a lb.
3/10 grade 49.2 lbs. nitrogen for $30 or 61 cts. a lb.
4/10 grade 65.6 lbs. nitrogen for $37 or 56.4 cts. a lb.

Potash seemed to cost at retail in Vermont in mixed goods about 25 cts. a pound, if one may judge by the above prices.

Now the University was in the market last spring to buy plant food. It bought crude stock, unmixed ingredients, and paid cash, as any farmer with ready money or good credit might have done. It paid for nitrogen in two forms, 33.3 and 37.4 cts. a pound, which compare favorably with 56.4 to 140 cts. a pound; it paid 7.8 cts. a pound for available phosphoric acid, which is somewhat less than 10 cts.; and it bought no potash whatsoever, because it was not thought that a new dollar in crop growth would be likely to replace an old one spent for potash.

Farmers who bought cooperatively through farmers' exchanges in 1920 as in previous years bought at a considerable saving as compared with the usual methods of purchase.

The average fertilizer sold in all probability for about $50, an advance of nearly 50 percent over the prices asked during 1915-17.

## FEEDING STUFFS INSPECTION

The sampling agents of the Station visited about 50 cities, towns and villages in Vermont in the spring of 1920, and drew 563 samples from dealers' stocks, representing 289 brands of goods which either are subject to or exempt from the necessity of guaranty. The samples have been examined chemically for protein only.

The law seems fairly well observed at present. Unguaranteed goods are infrequent at the present time and overguaranties are not as common as once they were; but overstatements in advertising occur.

The following condensed statements set forth the facts as to protein guaranty maintenance as determined in the present inspection. Within groups, the order of statement is alphabetical by names of manufacturers or jobbers. Manufacturers' or jobbers' names and addresses are printed in SMALL CAPITALS, brand names in *italics,* guaranties in figures in parenthesis following the brand name. The deficiency in protein content, if any, is stated following the guaranty in *italics.*

## COTTONSEED MEALS

### PROTEIN GUARANTIES FULFILLED

Ashcroft-Wilkinson Co., Atlanta, Ga., *Paramount* (36). F. W. Brodé Co., Memphis, Tenn., *Jay* (36). Buckeye Cotton Oil Co., Cincinnati, O., *Buckeye Good* (36). Cottonseed Products Co., Louisville, Ky., *Good* (36). Humphreys, Godwin Co., Memphis, Tenn., *Bull* (43); *Danish* (36). Lyle & Lyle, Huntsville, Ala., *Economy* (36). J. E. Soper Co., Boston, Mass., *Pioneer* (36); *Puritan* (36). Union Seed & Fertilizer Co., Montgomery, Ala., *Surety* (36).

### PROTEIN GUARANTIES NOT FULFILLED

East St. Louis Cotton Oil Co., East St. Louis, Ill., *St. Clair* (guaranty 36, analysis 35.5). Farmers' Cotton Oil & Trading Co., Uniontown, Ala., (guaranty 36, analysis 34).

## COTTONSEED FEED MEAL

### PROTEIN GUARANTY FULFILLED

Union Seed & Fertilizer Co., Huntsville, Ala., *Columbia* (20.56). (The local dealer reports this lot as consisting of "only seven bags in a lot sent by mistake." As a matter of fact this was really cottonseed meal carrying 35% protein, placed in cottonseed feed bags.)

## LINSEED MEALS

### PROTEIN GUARANTIES FULFILLED

American Linseed Co., Buffalo, N. Y., *Old Process* (34). American Milling Co., Peoria, Ill., *Old Process* (30). Midland Linseed Products Co., Minneapolis, Minn., *Argentine Old Process* (30); ———— (32); *Midland Old Process* (30); ———— (32). Spencer Kellogg & Sons, Inc., Buffalo, N. Y., *Pure Old Process* (30).

### PROTEIN GUARANTIES NOT FULFILLED

American Linseed Co., Chicago, Ill., *Old Process* (guaranty 34, analysis 31.6). Archer & Daniels Linseed Co., Buffalo, N. Y., *Old Process* (guaranty 34, analysis 31.1). Midland Linseed Products Co., Minneapolis, Minn., *Old Process* (guaranty 32, analysis 30.9). Spencer Kellogg & Sons, Inc., Underclif, N. J., *Pure Old Process* (guaranty 31, analysis 30.4). Spencer Kellogg & Sons, Inc., Buffalo, N. Y., *Pure Old Process* (guaranty 33, analysis 31.4).

## GLUTEN FEEDS

### PROTEIN GUARANTIES FULFILLED

American Maize Products Co., New York, N. Y., *Cream of Corn* (23). Clinton Sugar Refining Co., Clinton, Iowa, *Clinton* (23). Corn Products Refining Co., New York, N. Y., *Buffalo* (23). A. E. Staley Manufacturing Co., Decatur, Ill., *Staley's* (20). United States Food Products Corporation, Peoria, Ill., *Farmer Jones* (23).

## BREWERS' DRIED GRAINS

### PROTEIN GUARANTIES FULFILLED

Farmers' Feed Co., Buffalo, N. Y., *Bull* (27.2). Fleischmann Co., Peekskill, N. Y., *Fleischmann's* (17); *Fleischmann's* (16); *Fleischmann's Dried Malt Grains* (22).

## PEANUT FEED—COCOANUT MEAL—VELVET BEAN MEAL

### PROTEIN GUARANTIES FULFILLED

Humphreys, Godwin Co., Memphis, Tenn., *Peanut Feed, Liberty Brand* (30). Spencer Kellogg & Sons, Inc., Undercliff, N. J., *Cocoanut Meal* (20). Humphreys, Godwin Co., Memphis, Tenn., *Velvet Bean Meal, Digesto Brand* (17).

## WHEAT OFFALS—BRAN

### PROTEIN GUARANTIES FULFILLED

Acme-Evans Co., Indianapolis, Ind., *Acme* (15.5); *Acme* (15.5). E. W. Bailey & Co., Montpelier, Vt., *Pennant* (14.5). Samuel Bell & Sons, ————, ———., *Bellson* (13). Cannon Valley Milling Co., Minneapolis, Minn., *C. V.* (15). Century Milling Co., ————, ———., *Jersey* (13). Commercial Milling Co., Detroit, Mich., ———— (14.5). Consolidated Flour Mills Co., Hutchinson, Kan., *Wheat Bran and* (not to exceed 8% ground wheat) *screenings* (14.5). Consolidated Milling Co., ————, ———., *Pure* (14.5). Everett Auchenbaugh & Co., ————, ———., *E. A. Co.* (14). Federal Milling Co., Lockport, N. Y., *Lucky* (13); *Dairy Maid* (12.5); *Lucky* (12). Ismert-Huck Co., Kansas City, Mo., *I-H* (14.5). Larrabee Flour Mills Corporation, Kansas City, Mo., *Larrabee* (15). H. D. Lee Flour Mills Co., ————, ———., *Wheat Bran with* (not to exceed 8%) *screenings* (14.5). Lee-Warren Milling Co., ————, ———., ———— (14.5). New Prague Milling Co., New Prague, Minn., *Seal of Minnesota* (13.3). Northwestern Consolidated Milling Co., Minneapolis, Minn., ———— (14.5). Ogdensburg Roller Mills Co., Ogdensburg, N. Y., *Ogdensburg* (14). Pillsbury Flour Mills Co., Minneapolis, Minn., *Pillsbury's Durum* (11); *Pillsbury's* (13). Red Wing Milling Co., Red Wing, Minn., *Bixota* (13.5). Russell-Miller Milling Co., Minneapolis, Minn., *Russell-Miller* (13). Southwestern Milling Co., Kansas City, Mo., *Red Turkey* (14.5). David Stott Flour Mills, Inc., Detroit, Mich., *Bran and Screenings* (14.5); ———— (11). Thompson Milling Co., Lockport, N. Y., *Angelus* (11). Washburn-Crosby Co., Minneapolis, Minn., *Washburn-Crosby* (13). Wichita Flour Mills Co., Wichita, Kan., *Wheat Bran and Screenings* (14.5).

### PROTEIN GUARANTIES NOT FULFILLED OR UNGUARANTEED

Russell-Miller Milling Co., Minneapolis, Minn., ———— (guaranty 19, analysis 17.1). Bill, Bell & Co., Ogdensburg, N. Y., ———— (guaranty —, analysis 15.6).

## WHEAT OFFALS—MIDDLINGS

### PROTEIN GUARANTIES FULFILLED

Aberdeen Mills, Aberdeen, So. Dak., *Mulse Fancy* (15.6). Bill, Bell & Co., Ogdensburg, N. Y., *Shorts* (16). Cannon Valley Milling Co., Minneapolis, Minn., *C. V.* (16). C. S. Christensen Co., Madelia, Minn., *Flour*

(14.25). Commercial Milling Co., Detroit, Mich., *Standard White* (13.5). Federal Milling Co., Lockport, N. Y., *Dairy Maid* (13). Lawrenceburg Roller Mills Co., Dearborn, Ind., *Golden Bull* (16); ——— (15.5). Northwestern Consolidated Milling Co., Minneapolis, Minn., *Standard* (15). Pillsbury Flour Mills Co., Minneapolis, Minn., *Pillsbury's A* (15); *Pillsbury's B* (14); *Pillsbury's Standard* (14); *XX Daisy* (10). Russell-Miller Milling Co., Minneapolis, Minn., *Alta* (15). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (14.5); *Wirthmore* (14); *War Grade* (13). Slane Bros. & Wilson Co., ———, ——., *Snowball* (16.5); *O* (16). Southwestern Milling Co., Inc., Kansas City, Mo., *Wheat Brown Shorts*, containing not more than 5% of wheat screenings (15). Stern Milling Co., Milwaukee, Wis., *Rye* (14). David Stott Flour Mills, Inc., Detroit, Mich., *Pennant* (15). Thompson Milling Co., Lockport, N. Y., *Angelus* (11). Valley City Milling Co., Grand Rapids, Mich., *Rowena* (16.5). Voight Milling Co., Grand Rapids, Mich., *Crescent* (14). Washburn-Crosby Co., Minneapolis, Minn., *Arlington* (14); ——— *Standard* (14).

### UNGUARANTEED

Ogdensburg Roller Mills Co., Ogdensburg, N. Y., *Germ* (guaranty —, analysis 17.1); *Winter* (guaranty —, analysis 16.4). ———, *White* (guaranty —, analysis 18.4). ———, *Amazon* (guaranty —, analysis 15).

## WHEAT OFFALS—MIXED FEEDS

### PROTEIN GUARANTIES FULFILLED

E. W. Bailey & Co., Montpelier, Vt., *Capital* (14); *Bailey's Fancy* (15). Bill, Bell & Co., Ogdensburg, N. Y., *Wise King* (15). Capital City Milling & Grain Co., St. Paul, Minn., *St. Paul Queen* (14.3). Federal Milling Co., Lockport, N. Y., *Dairy Maid* (13). Hannibal Milling Co., ———, ——., *Red Star* (15.5). J. H. Hewitt, So. Royalton, Vt., *Our* (15). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (15). F. W. Kelley Co., St. Johnsbury, Vt., *Blue Tag* (15). National Milling Co., Toledo, Ohio, *Pennant* (13); *Osota* (15). Niagara Falls Milling Co., Niagara Falls, N. Y., *Perfect* (14). Northwestern Consolidated Milling Co., Minneapolis, Minn., *Planet* (15). Portland Milling Co., Portland, Mich., *Champion* (13.56). Pillsbury Flour Mills Co., Minneapolis, Minn., *Pillsbury's XX Daisy* (16); *Pillsbury's* (14). Quaker Oats Co., Chicago, Ill., *Buckeye* (15.5). Russell-Miller Milling Co., Minneapolis, Minn., *Occident* (15). Royal Milling Co., Great Falls, Mont., *Royal* (15). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (15); *Hygrade* (16). Star & Crescent Milling Co., ———, ——., *Star* (15). Sheffield-King Milling Co., Minneapolis, Minn., *Gold Mine* (15). Thompson Milling Co., Lockport, N. Y., *Angelus* (11).

### PROTEIN GUARANTIES NOT FULFILLED OR UNGUARANTEED

E. Crosby & Co., Brattleboro, Vt., *Crosby's* (guaranty 16, analysis 15.4). A. H. McLeod Milling Co., St. Johnsbury, Vt., *Brooks' Fancy* (guaranty 16, analysis 14.8). Ogdensburg Roller Mills Co., Ogdensburg, N. Y., *Winter* (guaranty —, analysis 16.4).

## WHEAT OFFALS—RED DOG FLOUR

### PROTEIN GUARANTIES FULFILLED

Eagle Milling Co., ———, ——., ——— (16). Duluth-Superior Milling Co., Duluth, Minn., ——— (18.5). St. Albans Grain Co., St. Albans, Vt., ——— (15). Washburn-Crosby Milling Co., Minneapolis, Minn., *Adrain* (18); *Adrain* (16); ——— (16).

## RYE OFFALS—BARLEY PRODUCTS

### PROTEIN GUARANTIES FULFILLED

Boutwell Milling & Grain Co., Troy, N. Y., *Rye Feed* (13.5). A. V. Smith, Marcellus Falls, N. Y., *Barley Mixed Feed* (13). Washburn-Crosby Co., Minneapolis, Minn., *Barley Screenings* (6).

## GROUND OATS

William Donahue Co., Boston, Mass. (analysis 12.5). Burditt Bros., Rutland, Vt. (analysis 12.7). Jesse Spaulding, Ludlow, Vt. (analysis 12.3). Pollard Bros., Proctorsville, Vt. (analysis 11.8). E. W. Bailey & Co., Montpelier, Vt. (analysis 11.5).

## CORN MEAL

W. F. Cunningham, St. Albans, Vt. (analysis 9.2); (analysis 9.2). J. Rosenbaum, Chicago, Ill. (analysis 9.2). E. W. Bailey & Co., Montpelier, Vt. (analysis 9.4); (analysis 9.2). Burditt Bros., Rutland, Vt. (analysis 8.8). McCuen Milling Co., Ogdensburg, N. Y. (analysis 9.2); (analysis 9.4). St. Albans Grain Co., St. Albans, Vt. (analysis 9.2); *Hygrade* (analysis 9.6); *Roller Meal* (analysis 9). Jesse Spaulding, Ludlow, Vt., (analysis 8.8).

## PROVENDERS

Pollard Bros., Proctorsville, Vt. (analysis 10.5). E. W. Bailey & Co., Montpelier, Vt. (analysis 11.2).

## HOMINY FEEDS

### PROTEIN GUARANTIES FULFILLED

American Hominy Co., Indianaplis, Ind., *Homco* (10); *Homco* (9.5). Charles A. Krause Milling Co., Milwaukee, Wis., *Yellow* (10). Quaker Oats Co., Chicago, Ill., *Yellow* (10.5); *Yellow* (10.5); *Yellow* (9). Standard Cereal Co., Chillicothe, Ohio, *Logan* (9). Baltimore Pearl Hominy Co., Baltimore, Md., *Spring Grade* (10).

## DRIED BEET PULP

### PROTEIN GUARANTIES FULFILLED

Larrowe Milling Co., Detroit, Mich., ———— (8); ———— (8); ———— (8). Ubico Milling Co., Cincinnati, Ohio, ———— (8); ————(8).

## OAT OFFALS

### PROTEIN GUARANTIES FULFILLED

Armour Grain Co., Chicago, Ill., *Hulls* (5). Quaker Oats Co., Peterborouvh, Ont., *Hulls* (5). Purity Oats Co., Keokuk, Iowa, *Feed* (5).

### UNGUARANTEED

M. Neuller & Son, *Dust* (guaranty —, analysis 5.2).

## ALFALFA MEAL

### PROTEIN GUARANTY FULFILLED

Omaha Alfalfa Milling Co., Omaha, Neb., ———— (12).

## PROPRIETARY FEEDS—DAIRY

### PROTEIN GUARANTIES FULFILLED

Arcady Farms Milling Co., Chicago, Ill., *Certified Dairy Ration* (25); *Arcady* (16). Armour Grain Co., Chicago, Ill., *Armour's* (22). Burlington Flouring Co., Burlington, Vt., *Dairy H* (20). Caledonia County Farm Bureau Exchange, Inc., St. Johnsbury, Vt., *Farmers' Ideal Dairy Ration* (19). Chapin & Co., Hammond, Ind., *Triangle* (21); *Lactola* (16.5). Cloverleaf Milling Co., Buffalo, N. Y., *Master Grain Ration* (24); *Peerless Milk* (20); *Cloverleaf* (13.5). E. Crosby & Co., Brattleboro, Vt., *Crosby's Ready Ration* (25); *Crosby's 1918 Dairy*

*Ration* (25). Elmore Manufacturing Co., Oneonta, N. Y., *Elmore Milk Grains* (25). International Sugar Feed Co., Minneapolis, Minn., *International Diamond Dairy* (24); *International Ready Ration* (20). Larrowe Milling Co., Detroit, Mich., *Big 6 Complete Dairy Ration* (21); *Larro* (20). Maritime Trading Corporation, Buffalo, N. Y., *Bull Brand Dairy Ration* (24). Oswego Milling Co., Inc., Oswego, N. Y., *Uncle John's 20% Cow Feed* (20). Park & Pollard Co., Boston, Mass., *Stevens' 44 Dairy Ration* (24). G. E. Patterson & Co., Memphis, Tenn., *Quarto* (24). Quaker Oats Co., Chicago, Ill., *Big Q Dairy Ration* (21); *Big Q Dairy Ration* (21). Richmond Grain Co., Inc., Richmond, Vt., *Winter Grain Ration* (20). St. Albans Grain Co., St. Albans, Vt., *Wirthmore Balanced Ration* (24); *Paragon Dairy* (22). Ubiko Milling Co., Cincinnati, Ohio, *Union Grains; Biles' Ready Dairy Ration* (24); *Fourex Dairy Ration* (20). Vermont Feed Co., Burlington, Vt., *Waumbeck Butterfat Meal* (20).

#### PROTEIN GUARANTIES NOT FULFILLED

Chapin & Co., Hammond, Ind., *Unicorn Dairy Ration* (guaranty 26, analysis 25.3). City Feed Co., St. Albans, Vt., *Farmers' Favorite* (guaranty 25, analysis 24.5). Cloverleaf Milling Co., Buffalo, N. Y., *Big Clover Complete Ration* (guaranty 24, analysis 23). International Sugar Feed Co., Minneapolis, Minn., *International Special* (guaranty 15, analysis 14.4). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal Dairy Ration* (guaranty 24, analysis 23). N. N. Morse & Sons, Randolph, Vt., *Balanced Dairy Ration* (guaranty 24, analysis 21.4). Oswego Milling Co., Oswego, N. Y., *Seavey 24% Dairy Ration* (guaranty 24, analysis 22.9). United States Feed Co., Milwaukee, Wis., *Digesto Dairy Ration* (guaranty 20, analysis 16.4).

### PROPRIETARY FEEDS—STOCK

#### PROTEIN GUARANTIES FULFILLED

Acme-Evans Co., Indianapolis, Ind., *Acme* (8.5). Akron Feed & Milling Co., Akron, Ohio, *Portage* (8.5). Armour Grain Co., Chicago, Ill., *Armour's* (12). E. W. Bailey & Co., Montpelier, Vt., *Pennant* (9). Buffalo Cereal Co., Buffalo, N. Y., *Iroquois* (10). E. Crosby & Co., Brattleboro, Vt., *Crosby's* (9); *Zenith* (8.5). Charles M. Cox Co., Boston, Mass., *Charlestock* (6). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's* (10). N. N. Morse & Sons, Randolph, Vt., ——— (9). Purina Mills, Buffalo, N. Y., *Purina O-Molene* (9.7). Purity Oats Co., Davenport, Iowa, *Iowa* (10); *Iowa* (10). Quaker Oats Co., Chicago, Ill., *Schumacher* (10); *Schumacher* (10). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (9).

#### PROTEIN GUARANTIES NOT FULFILLED

F. D. Lapelle, Swanton, Vt., ——— (guaranty 9, analysis 8.8). David Stott Flour Mills, Inc., Detroit, Mich., *Stott's Winner Chop* (guaranty 10, analysis 9.7).

### PROPRIETARY FEEDS—CALF

#### PROTEIN GUARANTIES FULFILLED

Blatchford's Calf Meal Factory, Waukegan, Ill. (24); *Milk Mash* (20). Quaker Oats Co., Chicago, Ill., *Schumacher* (18).

#### PROTEIN GUARANTIES NOT FULFILLED

Cloverleaf Milling Co., Buffalo, N. Y., *Cloverleaf* (guaranty 25, analysis 23.9). Ryde & Co., Chicago, Ill., *Ryde's Cream* (guaranty 25, analysis 24.4).

## PROPRIETARY FEEDS—SWINE

### PROTEIN GUARANTIES FULFILLED

CHAPIN & CO., HAMMOND, IND., ***Bicorn Hog Feed*** (17.5). PARK & POLLARD CO., BOSTON, MASS., ***Go-Tuit Hog Ration*** (15). ST. ALBANS GRAIN CO., ST. ALBANS, VT., ***Wirthmore Pig Feed*** (18); ***Wirthmore Hog Feed*** (17); ***Wirthmore Hog Feed*** (17).

### PROTEIN GUARANTY NOT FULFILLED

N. N. MORSE & SONS, RANDOLPH, VT., ***Pig Feed*** (guaranty 18, analysis 16.7).

## PROPRIETARY FEEDS—POULTRY—MASHES

### PROTEIN GUARANTIES FULFILLED

E. CROSBY & CO., BRATTLEBORO, VT., ***Egg*** (16). F. D. LAPELLE, SWANTON, VT., ***Egg Producing*** (12). A. H. MCLEOD MILLING CO., ST. JOHNSBURY, VT., ***Green Mountain*** (19). PARK & POLLARD CO., BOSTON, MASS., ***Lay or Bust Dry*** (18). QUAKER OATS CO., CHICAGO, ILL., ***Full-O-Pep Dry*** (20); ***Full-O-Pep Growing*** (17). ST. ALBANS GRAIN CO., ST. ALBANS, VT., ***Wirthmore with Milk Albumen*** (20); ***Wirthmore with Milk Albumen*** (20); ***Wirthmore with Milk Albumen*** (20); ***Egg*** (16).

### PROTEIN GUARANTY NOT FULFILLED

D. H. GRANDIN MILLING CO., JAMESTOWN, N. Y., ***Grandin's Dry*** (guaranty 20, analysis 19.5).

## PROPRIETARY FEEDS—POULTRY—SCRATCH FEEDS

### PROTEIN GUARANTIES FULFILLED

E. CROSBY & CO., BRATTLEBORO, VT., ***Crosby's*** (10.5). D. H. GRANDIN & CO., JAMESTOWN, N. Y., ***Grandin's*** (10). E. T. & H. K. IDE, ST. JOHNSBURY, VT., ***Ideal*** (10). PARK & POLLARD CO., BOSTON, MASS., ***Red Ribbon*** (10); ***Blue Ribbon*** (10). PURINA MILLS, BUFFALO, N. Y., ***Purina*** (10). PURITY OATS CO., DAVENPORT, IOWA, ***Tomboy*** (10). QUAKER OATS CO., CHICAGO, ILL., ***Ful-O-Pep*** (10); ***Schumacher*** (10). ST. ALBANS GRAIN CO., ST. ALBANS, VT., ***Wirthmore*** (11).

### UNGUARANTEED

MCCUEN MILLING CO., CHICAGO, ILL., ***Red Feather*** (guaranty —, analysis 10.9).

## PROPRIETARY FEEDS—POULTRY—CHICK

### PROTEIN GUARANTIES FULFILLED

E. CROSBY & CO., BRATTLEBORO, VT., ***Crosby's*** (10). PURINA MILLS, BUFFALO, N. Y., ***Purina*** (10). PARK & POLLARD CO., BOSTON, MASS., ***Baby Buster*** (11); ***Growing*** (10); ***Red Ribbon*** (10). PURITY OATS CO., DAVENPORT, IOWA, ***Tomboy*** (10). QUAKER OATS CO., CHICAGO, ILL., ***Ful-O-Pep Little Chick*** (14); ***Ful-O-Pep Chick*** (14); ***Schumacher*** (10). ST. ALBANS GRAIN CO., ST. ALBANS, VT., ***Wirthmore Buttermilk Baby Chick*** (13.5); ***Wirthmore Gritless Chick*** (11).

## PROPRIETARY FEEDS—POULTRY—MISCELLANEOUS

### PROTEIN GUARANTIES FULFILLED

ARCADY FARMS MILLING CO., CHICAGO, ILL., ***Arcady Poultry*** (9). BURLINGTON RENDERING CO., BURLINGTON, VT., ***Burlington Poultry*** (44). PARK & POLLARD CO., BOSTON, MASS., ***Growing*** (10). ST. ALBANS GRAIN CO., ST. ALBANS, VT., ***Wirthmore Growing Feed with Milk Albumen and Scraps*** (15).

## DISCUSSION OF THE RESULTS OF INSPECTION

Samples were taken representing 37 brands of the high protein by-products (cottonseed and linseed meals, gluten feeds, brewers' dried grains, peanut feeds), 39 brands of low protein products other than wheat offals (hominy feed, dried beet pulp, provenders, corn meals, ground oats, barley and rye products, etc.), 96 brands of wheat offals (brans, middlings, mixed feeds, red dog flour) and 103 brands of proprietary brands (ready mixed rations for dairy cows, horses, poultry, calves, swine and stock in general).

| | Number of brands | Protein guaranties range from | Protein contents range from | Deficiencies | Unguaranteed |
|---|---|---|---|---|---|
| Cottonseed meals.......... | 12 | 43 to 36 | 43 to 34 | 2 | 0 |
| Cottonseed feed............ | 1 | 20.56 | 35 | 0 | 0 |
| Linseed meals............. | 12 | 34 to 30 | 35.5 to 30.3 | 5 | 0 |
| Gluten feeds............... | 5 | 23 to 20 | 28 to 24.1 | 0 | 0 |
| Brewers' dried grains...... | 4 | 27.2 to 16 | 27.2 to 16 | 0 | 0 |
| Peanut feed............... | 1 | 30 | 36.4 | 0 | 0 |
| Cocoanut meal............ | 1 | 20 | 22.4 | 0 | 0 |
| Velvet bean meal.......... | 1 | 17 | 17.5 | 0 | 0 |
| Wheat offals.............. | 96 | 19 to 11 | 18.4 to 14.3 | 3 | 6 |
| Wheat brans........... | 32 | 19 to 11 | 17.3 to 14.3 | 1 | 1 |
| Wheat middlings........ | 31 | 16.5 to 11 | 18.4 to 15.6 | 0 | 4 |
| Wheat mixed feeds..... | 27 | 16.5 to 11 | 18.4 to 14.9 | 2 | 1 |
| Red dog flours.......... | 6 | 18.5 to 15 | 18.4 to 16.2 | 0 | 0 |
| Hominy feeds............. | 8 | 10.5 to 9 | 11.4 to 10.3 | 0 | 0 |
| Dried beet pulp............ | 5 | 8 | 9.4 to 8.4 | 0 | 0 |
| Miscellaneous.............. | 26 | .. | 16.3 to 5.2 | .. | .. |
| Provender.............. | 2 | .. | 11.2 to 10.5 | .. | .. |
| Corn meal.............. | 11 | .. | 9.6 to 8.8 | .. | .. |
| Ground oats............ | 5 | .. | 12.7 to 11.8 | .. | .. |
| Rye and barley products | 3 | 13.5 to 6 | 16.3 to 9.4 | 0 | 0 |
| Alfalfa meal........... | 1 | 12 | 15.8 | 0 | 0 |
| Oat feeds............. | 4 | 5 | 7 to 5.2 | 0 | 1 |
| Proprietary feeds.......... | 103 | 40 to 9 | 47.8 to 8.6 | 14 | 2 |
| Dairy.................. | 38 | 26 to 13.5 | 29.8 to 14.7 | 8 | 0 |
| Stock.................. | 17 | 12 to 6 | 13.1 to 8.6 | 2 | 0 |
| Swine.................. | 6 | 18 to 15 | 20.2 to 16.7 | 1 | 0 |
| Poultry................ | 37 | 40 to 9 | 47.8 to 10.3 | 1 | 2 |
| Calf................... | 5 | 25 to 18 | 25.9 to 18.4 | 2 | 0 |
| Mashes............. | 11 | 20 to 16 | 27.4 to 19 | 1 | 0 |
| Scratch feeds........ | 11 | 11 to 9 | 12.1 to 10.3 | 0 | 2 |
| Chick feeds......... | 11 | 14 to 10 | 15.8 to 10.8 | 0 | 0 |
| General................ | 4 | 40 to 9 | 47.8 to 10.9 | 0 | 0 |
| Totals.................... | 275 | 40 to 5 | 47.8 to 5.2 | 21 | 3 |

The outcome is not materially unlike that observed in former years; indeed it is distinctly better than has been sometimes noted. Only five brands out of nearly 300 submitted to analysis showed deficiencies that can be regarded as serious. One lot of cottonseed meal (Farmers' Cotton Oil & Trading Co., Huntsville, Ala.) contains only 95% as much protein as it was guaranteed to contain; two lots of linseed meal (Archer & Daniels Linseed Co., Spencer Kellogg & Sons, Inc., both of Buffalo, N. Y.) contained, respectively, only 93% and 92% as much protein as they were guaranteed to contain; while two proprietary feeds, namely the Balanced Dairy Ration sold by N. N. Morse & Sons, of Randolph, Vt., and the Digesto Dairy Ration sold by the United States Feed Co., of Milwaukee, Wis., contained, respectively, only 89% and 82% as much protein as they were guaranteed to carry.

## AGRICULTURAL SEED INSPECTION

The Station sampling agents visited about 40 Vermont cities, towns and villages during June, 1920, and gathered 254 samples of agricultural seed offered for sale in the open markets by local dealers culture.

| | | | | | |
|---|---|---|---|---|---|
| Alfalfa | 6 | Timothy | 32 | Rape | 4 |
| Barley | 17 | Blue grass | 1 | Rye | 3 |
| Clover, alsike | 23 | Buckwheat | 6 | Soy beans | 3 |
| Clover, red | 29 | Clover, white | 1 | Sweet clover | 3 |
| Corn | 53 | Orchard grass | 4 | Sudan grass | 1 |
| Millet | 29 | Peas, field | 9 | Wheat | 1 |
| Oats | 6 | | | | |
| Redtop | 23 | | | | |

These samples were drawn in the official manner. Purity tests were made by the weight method and the germination tests were made according to the method employed by the Federal Department of Agri- as follows:

The notations in parenthesis, i. e. (14), refer to the comments on pages — to — under the head "Concerning Deficiencies."

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| **ALFALFA** | | | | |
| IXL | Conklin | 99.6 | 84 | 1980 |
| —— | Dickinson | 98.2 | 58 | 630 |
| Monadnock | Holbrook | 99 | 66 | 900 |
| Honor | Standard | 98 | 79 | 3420 |
| Eureka | Whit.-Eck. | 99.5 | 89 | 630 |
| Ace | ? | *98.9* (1) | (2) 23 | 2970 |
| **BARLEY** | | | | |
| Six-row | Bailey | 98 | 73 | — |
| —— | Bailey | 96.5 | 85 | — |
| —— | Bailey | *97.8* (1) | 80 | 150 |
| —— | Bailey | 98 | 87 | 15 |
| 101949 | Bailey | 95 | 70 | — |
| Six-row | Bailey | 97.5 | 100 | — |
| —— | Breck | 97 | 69 | 15 |
| Oderbrucker | Conklin | 98 | 96 | — |
| Two-row | Conklin | 97.35 | 99 | — |
| Oderbrucker | Conklin | 97.04 (3) | 92 | 30 |
| —— | Dickinson | *99.2* (1) | 55 | — |
| 101980 | Dickinson | 97.5 (4) | 98 | — |
| 101993 | Dickinson | 94 | 68 | — |
| —— | Lapelle | 98 (5) | 91 | — |
| —— | Morehouse | 99 (6) | 79 | — |
| 7383 | Stanford | 90 | 83 | 60 |
| —— | Sweat-Comings | *99.64* | 89 | — |
| **ALSIKE CLOVER** | | | | |
| —— | Bailey | 94.5 | 77 | 3150 |
| Pine Tree | Bailey | 90.55 | 81 | 7200 |
| Ace | Bailey | 90.55 | 88 | 6300 |
| Imperial | Conklin | 98.1 | 47 | 2025 |
| —— | Conklin | 95 | 81 | 5625 |
| —— | Dickinson | *95.5* (1) | 87 | 2025 |
| Ace | Dickinson | 94.5 | 69 | 9000 |
| —— | Dickinson | 97 (7) | 84 | 225 |
| 86707 | Dickinson | 90 | 65 | 2475 |
| Freedom | Doughton | 96.5 (8) | 77 | 7200 |
| White Mountain | Holbrook | 98 (9) | 80 | 1350 |
| Ace | Holbrook | 95 (10) | 92 | 4050 |
| XX | Holbrook | 84 (11) | 74 | 7425 |
| Pine Tree | Holbrook | *96.25* (1) | 98 | 1125 |
| —— | Milwaukee | 99 (12) | 75 | 27450 |
| —— | Morehouse | 99.95 | 96 | 675 |
| —— | Nung.-Dick. | *96.5* (1) | 78 | 2475 |
| Arc | Stanford | 95 (13) | 77 | 1350 |
| Arc | Stanford | 97 (14) | 73 | 9900 |
| 9575 | Stanford | 94 (15) | 70 | 7425 |
| —— | Whit.-Eck. | *97.5* (1) | 88 | 450 |
| Eureka | Whit.-Eck. | *96.5* (1) | 65 | 3325 |
| Ace D | ? | 94 (16) | 81 | 900 |
| **RED CLOVER** | | | | |
| —— | Bailey | 97.5 | 89 | 3960 |
| —— | Bailey | 98 (17) | 81 | 2070 |
| —— | Breck | 98 (18) | 80 | 2610 |
| Crown | Conklin | 99.35 | 81 | 720 |
| Ace 124165 | Crav.-Dick. | 96.7 | 46 | 5040 |

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| — | Dibble | 99.7 | 84 | 450 |
| Globe | Dickinson | 99.6 | 89 | 720 |
| Pine Tree | Dickinson | 98.5 | 90 | 1350 |
| Pine Tree | Dickinson | 98.3 | 86 | 3240 |
| — | Dickinson | 97.8 (19) | 82 | 3090 |
| N. N. Y. | Dickinson | 98.5 (20) | 86 | 4950 |
| 73534 | Dickinson | 89.2 (21) | 86 | 10530* |
| Ace A | Doughton | 99 | 94 | — |
| White Mountain | Holbrook | 99.5 | 90 | 270 |
| — | Holbrook | 99.2 | 0 | 180 |
| XXX | Holbrook | 96 (22) | 3 | 4140 |
| XX | Holbrook | 95 (23) | 76 | 8370 |
| Pine Tree | Holl.-Hurl. | *99.76* | 93 | 720 |
| Mammoth | Lapelle | 99 | 93 | 630 |
| — | Milwaukee | 99 (24) | 78 | 18810 |
| — | Morehouse | 99.5 (25) | 96 | 630 |
| — | Nung.-Dick. | *98* (1) | 94 | 1890 |
| Honor | Stanford | 98 | 84 | 360 |
| 73464 | Stanford | 97 (26) | 85 | 8190 |
| Ace | Varrick | 99 | 56 | 2880 |
| Ace | Varrick | 98 | 68 | 1980 |
| Eureka | Whit.-Eck. | 99.5 | 90 | 360 |
| Eureka | Whit.-Eck. | 99 | 67 | 720 |
| Pan-American | Whit.-Eck. | 98 | 66 | 1170 |
| | CORN | | | |
| Longfellow | Bailey | 95 | 74 | — |
| Pride of the North | Bailey | 97.8 | 90 | — |
| Longfellow | Bailey | 99 | 89 | — |
| Sanford White Flint | Bailey | 99 (27) | 70 | — |
| Leaming | Bailey | 99.8 (28) | 73 | — |
| Sanford | Bailey | 95 | 73 | — |
| Early Crosby | Breck | 97 | 54 | — |
| Early Sanford | Breck | 98 | 73 | — |
| Early Sanford | Breck | 98 | 73 | — |
| Sanford | Breck | 97 | 44 | — |
| Sheffield Flint | Clark | 100 | 86 | — |
| Canada Flint | Clark | 90 | 86 | — |
| Pride of Nishua | Champlain | 95 | 76 | — |
| Sanford | Champlain | 92 | 91 | — |
| Burlington Dent | Champlain | 95 | 45 | — |
| Early 8-row Canada | Champlain | 92 | 71 | — |
| Early Wonder | Conklin | 95.5 | 62 | — |
| Pyramid Yellow Flint | Conklin | 99 | 75 | — |
| Pride of the North | Conklin | 99.66 | 59 | — |
| Eureka | Conklin | 99 | 99 | — |
| Early Wonder | Conklin | 99.2 (29) | 96 | — |
| — | Conklin | 99.5 (30) | 60 | — |
| Leaming | Conklin | 99.12 (31) | 72 | — |
| Longfellow | Crav.-Dick. | 99 | 77 | — |
| — | Dibble | 99 | 87 | — |
| N. Y. Flint | Dibble | *98.7* | 86 | — |
| White Flint | Dibble | *98.6* | 68 | — |
| Pride of the North | Dickinson | 99 | 84 | — |
| — | Dickinson | 99.8 (32) | 75 | — |
| Smutnose | Eberling | *98.18* | 76 | — |
| Sheffield | Emerson | *99.7* | 88 | — |
| Pride of Nishua | Gunson | 94 | 89 | — |
| Canada Flint | Holbrook | *99.66* | 42 | — |
| Eureka | Holbrook | *100* | 58 | — |

*Contained dodder.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Eureka | Lapelle | *100* | 92 | — |
| Pride of Nishua | Michigan | 94 | 60 | — |
| Minnesota King | Morehouse | 98 | 64 | — |
| Eight-row Flint | Page | *100* | 77 | — |
| West Branch | Page | *100* | [illegible]4 | — |
| Leaming | Page | 97 | 85 | — |
| Sanford | Rice | *100* | 40 | — |
| Red Cob | Rice | *99.46* | 68 | — |
| Vermont Dent | Rice | 90 | 68 | — |
| Eureka | Rice | *99.2* | 88 | — |
| 7484 | Stanford | 95 | 86 | — |
| 7285 | Stanford | 95 | 85 | — |
| 7396 | Stanford | 95 | 72 | — |
| 391 | Stanford | 95 | 77 | — |
| 7463 | Stanford | 95 | 85 | — |
| Leaming | Whit.-Eck. | 98 | 25 | — |
| Pride of the North | Whit.-Eck. | 98 | 85 | — |
| —— | Whit.-Eck. | 98 | 8 | — |
| New Blood Butcher | Whit.-Eck. | 90 | 94 | — |
| —— | —— | 85 | 88 | — |
| | | **MILLET** | | |
| Hungarian | Bailey | 99.6 | 54 | — |
| Japanese | Bailey | 94 | 60 | 180 |
| —— | Bailey | 98.5 | 70 | 720 |
| Hungarian | Bailey | 98.7 | 85 | 630 |
| Japanese | Breck | 98 | 37 | 180 |
| Japanese | Breck | *97.8* | 47 | 195 |
| Hungarian | Conklin | 99.75 | 77 | — |
| Japanese | Conklin | 97.2 | 78 | 630 |
| Japanese | Conklin | 98.7 | 68 | 720 |
| Liberty | Conklin | 98.2 | 42 | 3960 |
| Hungarian 80302 | Dickinson | 99.75 | 23 | — |
| German | Dickinson | 99.22 | 59 | 720 |
| Hungarian | Dickinson | 99.6 | 86 | 270 |
| Hungarian 80295 | Dickinson | 98.7 | 79 | 1620 |
| Hungarian | Dickinson | 98 | 66 | 990 |
| Hungarian | Dickinson | *99* (1) | 61 | 810 |
| Golden | Dickinson | 99 | 27 | 1620 |
| Japanese 48733 | Dickinson | 97 | 65 | 810 |
| Hungarian | Holbrook | 97 | 48 | 2340 |
| Japanese | Holbrook | 84 | 53 | 2140 |
| Japanese | Nung.-Dick. | *98.2* (1) | 16 | 1710 |
| German | Stanford | 98 | 41 | 1170 |
| Japanese | Stanford | 95 | 4 | 1170 |
| Japanese | Stanford | 96 | 55 | 1620 |
| Hungarian | Stanford | 91 | 44 | 6030 |
| Japanese | Stanford | 95.89 | 52 | 1710 |
| Hungarian | Whit.-Eck. | 97 | 56 | 1620 |
| Hungarian | —— | 97 | 28 | 1260 |
| Japanese | Whit.-Eck. | 97 | 55 | 6840 |
| | | **OATS** | | |
| Pennant | Bailey | 99.5 (33) | 88 | — |
| Northern Wonder | Conklin | 98.8 (34) | 81 | 15 |
| Extra Fancy White Mountain | Holbrook | 99 | 94 | — |
| White Mountain | Holbrook | 99 | 82 | — |
| Marsh | Marsh | 99.99 (35) | 84 | — |
| —— | St. Albans | *99.27* (1) | 99 | 15 |

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| **RED TOP** | | | | |
| Ace | Bailey | 92 | 11 | 4950 (A) |
| Ace | Bailey | 90 (36) | 33 | 46800 (A) |
| ———— | Bailey | 90 (37) | 41 | 94950 (B) |
| Imperial | Conklin | 93.36 | 10 | 4050 |
| Fancy Imperial | Conklin | *89.5* (1) | 12 | 17550 |
| ———— | Conklin | 85 | 13 | 59400 |
| ———— | Dickinson | 92 (38) | 1 | 9450 (A) |
| Fancy | Dickinson | 83 | 10 | 67950 (C) |
| Ace | Dickinson | 90 (39) | 21 | 30150 (B) |
| White Mountain | Holbrook | 95 | 33 | 18900 (A) |
| White Mountain | Holbrook | 95 | 15 | 27450 (A) |
| XXX | Holbrook | 90 | 22 | 2250 |
| Ace | Holbrook | 90 | 24 | 45550 |
| XX | Holbrook | 80 | 4 | 177750 |
| XX | Holbrook | 80 | 4 | 175500 (D) |
| Eureka | Middlebrook | 90 | 43 | 32850 |
| ———— | Middlebrook | 90 | 8 | 18450 (E) |
| ———— | Stanford | 85 | 35 | 187200 (F) |
| ———— | Whit.-Eck. | 94 | 14 | 29700 |
| Pan-American | Whit.-Eck. | 90 | 24 | 45900 |
| Eureka | Whit.-Eck. | 92 (40) | 45 | 5850 |
| XX | Whit.-Eck. | 80 | 24 | 103950 |
| Ace | ———— | *90* (1) | 17 | 25650 |
| **TIMOTHY** | | | | |
| ———— | Bailey | 99.6 | 61 | 225 |
| Pine Tree | Bailey | 99.5 | 61 | — |
| Pine Tree | Bailey | 99.6 (41) | 18 | — |
| Pine Tree | Bailey | 99.6 (42) | 40 | 675 |
| Pine Tree | Barb.-Benn. | 99.5 | 43 | 450 |
| Acme | Conklin | 99.8 | 66 | 225 |
| Bingo | Conklin | 99.95 (43) | 62 | — |
| Dibble's Best | Dibble | 99.7 (44) | 72 | 450 |
| Globe | Dickinson | *99.5* (1) | 52 | — |
| Pine Tree | Dickinson | 99.5 (45) | 72 | 675 |
| Pine Tree | Dickinson | *99* (1) | 31 | 450 (A) |
| Pine Tree | Dickinson | *99.5* (46) | 63 | 225 (A) |
| ———— | Dickincon | 99.6 (47) | 50 | 450 (A) |
| 64982 | Dickinson | 98.35 | 61 | 2925 (A) |
| 65233 | Dickinson | 98.2 (48) | 55 | 2250 (A) |
| XX | Holbrook | 98 | 53 | 3825 |
| White Mountain | Holbrook | 99.85 (49) | 34 | 450 |
| Extra Fancy | Holbrook | 99.85 (50) | 34 | 225 |
| ———— | Holbrook | 98 | 66 | 4725 |
| Pine Tree 65219 | Holbrook | 99.6 (51) | 12 | — (A) |
| Freedom | Middlebrook | 99.5 | 25 | — |
| ———— | Morehouse | 99 | 28 | — |
| Pine Tree | Nung.-Dick. | 99.5 (52) | 66 | — |
| ———— | Stanford | 99.5 (53) | 61 | — |
| Liberty 9643 | Stanford | 99.5 | 51 | — |
| ———— | Stanford | 99.5 (54) | 25 | 450 |
| Durham | Varick | 99 | 71 | — |
| Pan-American | Whit.-Eck. | 99.5 | 78 | 225 |
| Pan-American | Whit.-Eck. | 98 | 20 | 225 |
| Gold Medal | Whit.-Eck. | 99.7 | 4 | 225 |
| Gold Medal | Whit.-Eck. | 99.55 | 4 | — |
| Pan-American | Whit.-Eck. | 89.5 | 80 | 1575 |

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| MISCELLANEOUS | | | | |
| Buckwheat (Japanese) | Conklin | 98.9 | 72 | 60 |
| Buckwheat (Japanese) | Conklin | 98 | 76 | 30 |
| Buckwheat | Holbrook | 98.5 | 73 | — |
| Buckwheat | Whit.-Eck. | 98 | 60 | 630 |
| Buckwheat | Whit.-Eck. | 98 (55) | 80 | 690 |
| India Wheat | McLeod | *97.67* (1) | 92 | 150 |
| Blue Grass | Dickinson | *82.5* (1) | 4 | 22500 |
| Orchard Grass | Bailey | *94* (1) | 10 | 1125 |
| Orchard Grass | Dickinson | 78 | 4 | 900 |
| Orchard Grass | Dickinson | *83.5* (1) | 13 | 225 |
| Orchard Grass | Dickinson | 88.7 (56) | 10 | 7425 |
| Canada Peas | Bailey | 98 | 97 | — |
| Canada Peas | Dickinson | *99.4* (2) | 23 | — |
| Canada Peas | Dickinson | 98.9 (2) | 76 | — |
| Canada Peas | Dickinson | 99.76 | 18 | — |
| Canada Peas | Holbrook | *97.16* (2) | 56 | — |
| Canada Peas | Holbrook | *99.2* (28) | 98 | — |
| Canada Peas | Whit.-Eck. | 98 | 4 | — |
| Canada Peas | Whit.-Eck. | 98 | 74 | — |
| Canada Peas | — | *98.3* | 91 | — |
| Rape | Dickinson | 99 | 95 | — |
| Rape | Stanford | 99 | 89 | — |
| Rape | Stanford | 98.94 | 36 | — |
| Rape | Whit.-Eck. | 98 | 93 | — |
| Rye (Winter) | Bailey | 98 (57) | 11 | 195 |
| Rye 101926 | Dickinson | 99.5 | 98 | — |
| Rye (Spring) | Whit.-Eck. | 98 (58) | 17 | 45 |
| White Sweet Clover | Conklin | 99.6 | ? | — |
| White Sweet Clover | Dickinson | 98.38 | 62 | 9630 |
| White Sweet Clover | Holbrook | 97 (59) | 77 | 2520 |
| Soy Beans | Bailey | *98.6* (52) | 2 | 18 |
| Soy Beans | Breck | *94.56* (52) | 57 | — |
| Soy Beans | — | *100* (2) | 0 | — |
| Sudan Grass | Doughton | *93.8* (1) | 29 | 180 |
| Wheat | Bailey | 98 | 59 | 30 |
| White Clover | Dickinson | 91.15 | 39 | 4500 |

Several samples of red top and timothy showed ergot.

## CONCERNING DEFIENCIES

(1) Local seed merchants are notoriously careless in the matter of preserving guaranty tags. The law is mandatory but thoroughly ineffective in respect to guaranty displayal (see bulletin 205, pp. 12-13). The lack of guaranty statement in connection with the record against which the notation (1) occurs should not be construed as indicating a belief that the wholesaler did not furnish a guaranty as required by law, for as a matter of fact it has been developed in previous inspection that most of the seed men whose names are thus indicated have been very scrupulous in this respect. It means simply that the sampling

agents noted no such guaranties attached to the packages from which samples were drawn. The actual contents of pure seed found in each case is indicated in *italics,* since no guaranty statement can be furnished.

(2) No guaranties needed.

(3 to 59 inclusive) Guaranties not maintained in any instance, the figures being as indicated, the first figure indicating guaranty, the second, performance. (3) 97.04-96.3. (4) 97.5-96.04. (5) 98-92.8. (6) 99-96.5. (7) 97-94.25. (8) 96.5-93. (9) 98-97. (10) 95-93. (11) 84-83. (12) 99-75. (13) 95-94.5 (14) 97-93.5. (15) 94-92.15. (16) 94-93.5. (17) 98-97.6. (18) 98-97.4. (19) 97.8-96.6. (20) 98.5-95.2. (21) 89.2-80.6. (22) 96-92.6. (23) 95-91.4. (24) 99-90. (25) 99.5-99. (26) 97-96.36. (27) 99-98.56. (28) 99.8-97.9. (29) 99.2-98.2. (30) 99.5-97.7. (31) 99.12-97.3. (32) 99.8-99. (33) 99.5-99. (34) 98.8-98.4. (35) 99.99-99.27. (36) 90-89. (37) 90-87. (38) 92-91.5. (39) 90-88. (40) 92-88. (41) 99.6-99. (42) 99.6-98.75. (43) 99.95-97.25. (44) 99.7-99. (45) 99.5-99. (46) 99.5-99. (47) 99.6-99. (48) 99.2-97. (49) 99.85-99. (50) 99.85-98.5. (51) 99.6-98. (52) 99.5-99. (53) 99.5-97.5. (54) 99.5-99. (55) 98-97.33. (56) 88.7-75.5. (57) 98-95. (58) 98-92.47. (59) 97-95.6.

## DISCUSSION OF THE RESULTS OF INSPECTION

The violations of the law consist of:

(1) *Failure to declare guaranties.* This amounts to practical nullification, in so far as information touching guaranteed purity is concerned, supplied to the purchaser of the usual amounts from broken packages. The writer has no means of knowing with certainty but has every reason to believe that local merchants, as a rule, fail to affix "a plainly written or printed statement," "conspicuously" to "every lot or parcel of agricultural seed of five pounds or over sold for seeding purposes" "clearly and truly certifying the namer thereof and its minimum percentage of purity, " etc.

About 14 percent of the lots sampled by the station's agents bore no visible statement as to the purity of their contents. Almost invariably this information is furnished by the wholesaler, but very commonly the retailer pays no attention to and destroys it.

(2) *Failure to maintain quantities.* Twenty-two percent of the goods which were guaranteed were found to be deficient and seven percent were seriously deficient. Especial attention is called to these cases.

It is not to be wondered that there are several lapses in view of the extremely tenuous protection afforded by the Vermont law, which is about as toothless as it well can be.

*Barley.* Lapelle Poultry Food Co., Swanton, Vt. Guaranteed 98% pure, actually 92.8% pure. Contained more than 7% foreign seed, mainly oats, wheat and wild oats.

*Barley.* W. H. Morehouse Co., Toledo, Ohio. Guaranteed 99% pure, actually 96.5% pure. Contained 2.2% foreign seeds, mostly oats and wheat, and 1.3% inert matter.

*Alsike Clover.* Albert Dickinson Co., Chicago, Ill. Guaranteed 97% pure, actually 94.25% pure. Contained 4.8% foreign seed, mostly timothy and white clover, and 1% inert matter.

*Alsike Clover.* H. W. Doughton, Inc., New York, N. Y. Guaranteed 96.5% pure, actually 93% pure. Contained 6% foreign seed, mostly timothy and white clover, 7,200 weed seed per pound, and 1% inert matter.

*Alsike Clover.* Milwaukee Seed Co., Milwaukee, Wis. Guaranteed 99% pure, actually 75% pure. Contained 32.5% foreign seed, timothy, white and red clovers predominating, 27,450 weed seed per pound—18 varieties being found, with sheep sorrel, catchfly, black medick making up two-thirds of the lot by number—and 2.5% inert matter.

*Alsike Clover. Arc Brand.* Stanford Seed Co., Buffalo, N. Y. Guaranteed 97% pure, actually 93.5% pure. Contained 6% foreign seed, mostly timothy and white clover, and 9,900 weed seed per pound, mostly catchfly.

*Red Clover. N. N. Y. Brand.* Albert Dickinson Co., Chicago, Ill. Guaranteed 98.5% pure, actually 95.2% pure. Contained 3.4% foreign seed, mostly alfalfa and weed seed, comprising 16 varieties, mostly yellow foxtail, pigweed, wild carrot and the narrow leaved plantain, and 1.4% inert matter.

*Red Clover 73534.* Albert Dickinson & Co., Chicago, Ill. Guaranteed to contain 89.2% clover, and 4.2% alfalfa; actually contained 80.6 and 6.4 percents. Contained 10% of other foreign seed, including 10,530 weed seed per pound, mostly yellow foxtail and narrow leaved plantain, and 3% inert matter.

*Red Clover. XXX Brand.* Holbrook Grocery Co., Burlington, Vt. Guaranteed 96% pure, actually 92.6% pure. Contained 4% foreign seed, mostly alsike, timothy and yellow foxtail, 4,140 weed seed per pound, and 3.4% inert matter.

*Red Clover. XX Brand.* Holbrook Grocery Co., Burlington, Vt. Guaranteed 95% pure, actually 91.4% pure. Contained 5% foreign seed, including 8,370 weed seed per pound, the foreign seed consisting in the main of timothy, alsike clover, yellow foxtail, two forms of plantain and ragweed, and 3.6% inert matter.

*Red Clover.* Milwaukee Seed Co., Milwaukee, Wis. Guaranteed 99% pure, actually 90% pure. Contained 7% foreign seed, including 18,810 weed seed per pound, the foreign seed consisting in the main of timothy, alsike and white clovers, small crab-grass, pigweed, yellow foxtail, sweet clover, and two forms of plantain, and 3% inert matter.

*Red Top.* E. W. Bailey & Co., Montpelier, Vt. Guaranteed 90% pure, actually 87% pure. Contained 10% inert matter, and 3% foreign seed, mostly timothy, potentilla, yarrow and carex.

*Red Top. Eureka Brand.* Whitney-Eckstein Co., Buffalo, N. Y. Guaranteed 92% pure, actually 88% pure. Contained 11% inert matter.

*Timothy. Bingo Brand.* E. W. Conklin Co., Binghamton, N. Y. Guaranteed 99.5% pure, actually 97.25% pure. Contained 2.5% foreign seed, mostly red clover.

*Orchard Grass.* Albert Dickinson Co., Chicago, Ill. Guaranteed 88.7% pure, actually 75.5% pure. Contained 22% inert matter, and 2.5% foreign seed, mostly cheat. Germination nil.

*Winter Rye.* E. W. Bailey & Co., Montpelier, Vt. Guaranteed 98% pure, actually 95% pure. Contained 3.7% inert matter, mostly broken seed, and 1.3% foreign seed, mostly wheat, barley and dock. Germination 11%.

*Spring Rye.* Whitney-Eckstein Co., Buffalo, N. Y. Guaranteed 98% pure, actually 92.47% pure. Contained 6.7% inert matter.

## CONCERNING VIABILITY

The Vermont law does not require a seller to state the viability of his goods. Such a statement is required by the law in our sister state of New Hampshire as well as in some other states. Perhaps the Vermont law should include this item of information. However, from the outset the Station has annually reported upon the viability of the seed samples which it has gathered. It regrets to report that the results secured with the samples taken in 1920 are much less satisfactory than usual. The following table seems worth calling to the attention of the readers:

COMPARISON OF VIABILITY WITH STANDARDS

| Seed | Standard of viability | Samples | Above minimum standard | Below minimum standard |
|---|---|---|---|---|
| Alfalfa | 85-90 | 6 | 1 | 5 |
| Barley | 90-95 | 17 | 6 | 11 |
| Alsike clover | 75-80 | 23 | 16 | 7 |
| Red clover | 85-90 | 29 | 14 | 15 |
| Corn | 90-95 | 53 | 6 | 47 |
| Millet | 85-90 | 29 | 2 | 27 |
| Oats | 90-95 | 6 | 2 | 4 |
| Red top | 75-80 | 23 | 0 | 23 |
| Timothy | 85-90 | 32 | 0 | 32 |
| Buckwheat | 90-95 | 6 | 1 | 5 |
| Peas | 93-98 | 9 | 2 | 7 |
| Rape | 90-95 | 4 | 2 | 2 |
| Rye | 90-95 | 3 | 1 | 2 |
| | | 240 | 53 | 187 |

This is certainly a startling situation. If one may judge by the samples taken by the station's sampling agents 78% of the seeds sold in Vermont in 1920 were below the minimum standards of viability as determined by the federal seed experts and by the Association of Official Seed Analysts. Eight percent of the samples were so poor in viability that only one seed in ten or less would grow; four percent were so poor that only one seed in 25 or less would grow; and in three cases not a single seed was alive.

There is this much to be said, however, that the analyses for germination or viability are always made at this Station, and of necessity made, some week or even months after the samples are received and, consequently, the results may be somewhat lower than was actually the fact when the seed entered the State or was used, if it was used, in the months of May and June. The reason for this is the inadequate sum available for the conducting of seed inspection. However, the figures are so very low in many instances, that there is no escape from the conclusion that much of the seed, when used, was sub-standard as to its viability. Indeed it is not too much to say that probably the seed supplied in 1920 in Vermont was inferior in respect to guaranty maintenance, weed seed content, and viability to that furnished at any time since the seed law went into effect.

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FEBRURY, 1921 BULLETIN 221

University of Vermont and State Agricultural College

## Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# FIRST 15 YEARS OF A 40-VARIETY APPLE ORCHARD

# APPLE CION SELECTION FROM HIGH AND LOW YIELDING PARENT TREES

1791

BURLINGTON
Free Press Printing Company
1921

the winters of 1917-18 and 1918-19. The location of the station orchard on high land favored air drainage and was an important factor of protection. Furthermore, the discontinuance of cultivation in late summer and the sowing of cover crops were helpful procedures.

The yields for the several trees of each variety from the beginning of the orchard to the end of a 15-year period were ascertained by yearly records. The average number of apples per tree among the high producers was 4,927 for Longfield, 2,794 for Yellow Transparent, 2,729 for Scott, 2,601 for Oldenburg, 2,598 for Fameuse; among the low producers, 62 for Cooper, 118 for Gravenstein, 165 for Roman Stem, 207 for dwarf Baldwin, 264 for McIntosh, and 326 for Northern Spy. On the basis of pounds produced, the averages per tree were; high producers: Yellow Transparent, 854; Yellow Bellflower, 827; Longfield, 753; Oldenburg, 658; Fameuse, 605; low producers: Cooper, 15; Gravenstein, 30; Roman Stem, 39; dwarf Baldwin, 65; McIntosh, 74.

The storage endurance of many varieties in a basement room and under recorded conditions of temperature and humidity was studied for three seasons. Seven-day thermograph and hygrograph instruments were used and two-hour readings were secured from the dials of these instruments. The temperature and humidity conditions were not unlike those which may obtain in basement storerooms on Vermont farms. Ventilation was secured by the use of windows, moisture provided by creating water surfaces, and freezing prevented in severe weather by the use of oil stoves. During much of the time temperatures approximated 40° F. and the humidity was about 75. The highest humidity during the storage season of 1917-18 was 96, the lowest 67, and the average 86; during 1919-20, 83, 39 and 70 respectively. The temperature ranges for each season were: 1916-17; lowest 33°, highest 80°, average 50°; in 1917-18; lowest 32°, highest 78°, average 45°.

The three-year average storage period varied from 38 days for Red Astrachan and 154 days for St. Lawrence, to 297 days for Ben Davis and 324 days for Mann. Baldwin averaged 281 days; McIntosh, 224; Wealthy, 219; R. I. Greening, 241; Fameuse, 226; N. W. Greening, 236. Endurance varied somewhat with the season.

In general the progress of decay was slow and the shrinkage small. The percentage of loss in weight, up to the time of first decay, ranged from 3 percent for St. Lawrence to 26 percent for Oldenburg. It was 19 percent for Spitzenburg, 9 percent for McIntosh, 7 percent for Rhode Island Greening and 4 percent for Fameuse, but the time embraced was different in each case.

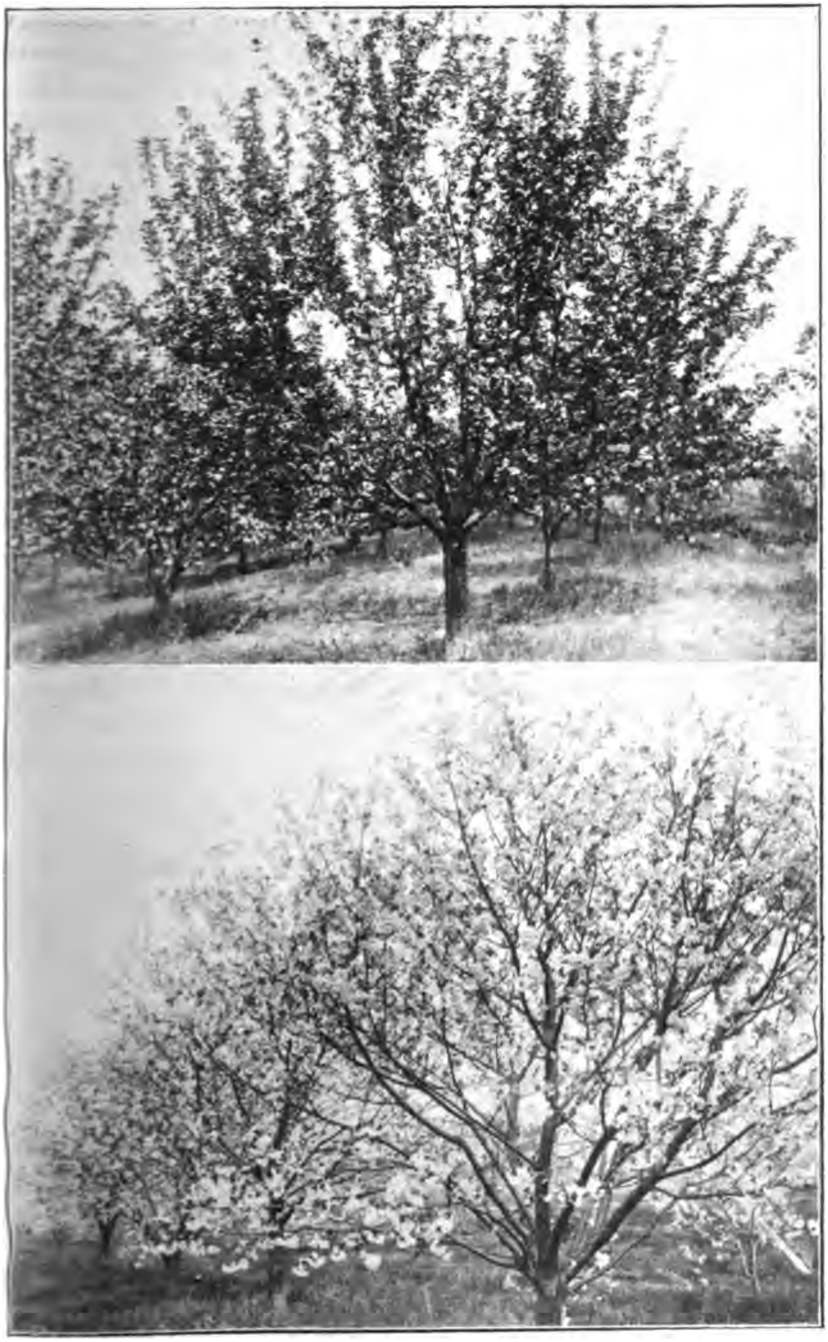


PLATE I—Fameuse tree in the foreground, showing the open nature of the top and general style of pruning employed (above).

A row of Fameuse trees in full bloom showing open head and scaffold system as well as height of base limbs (below).

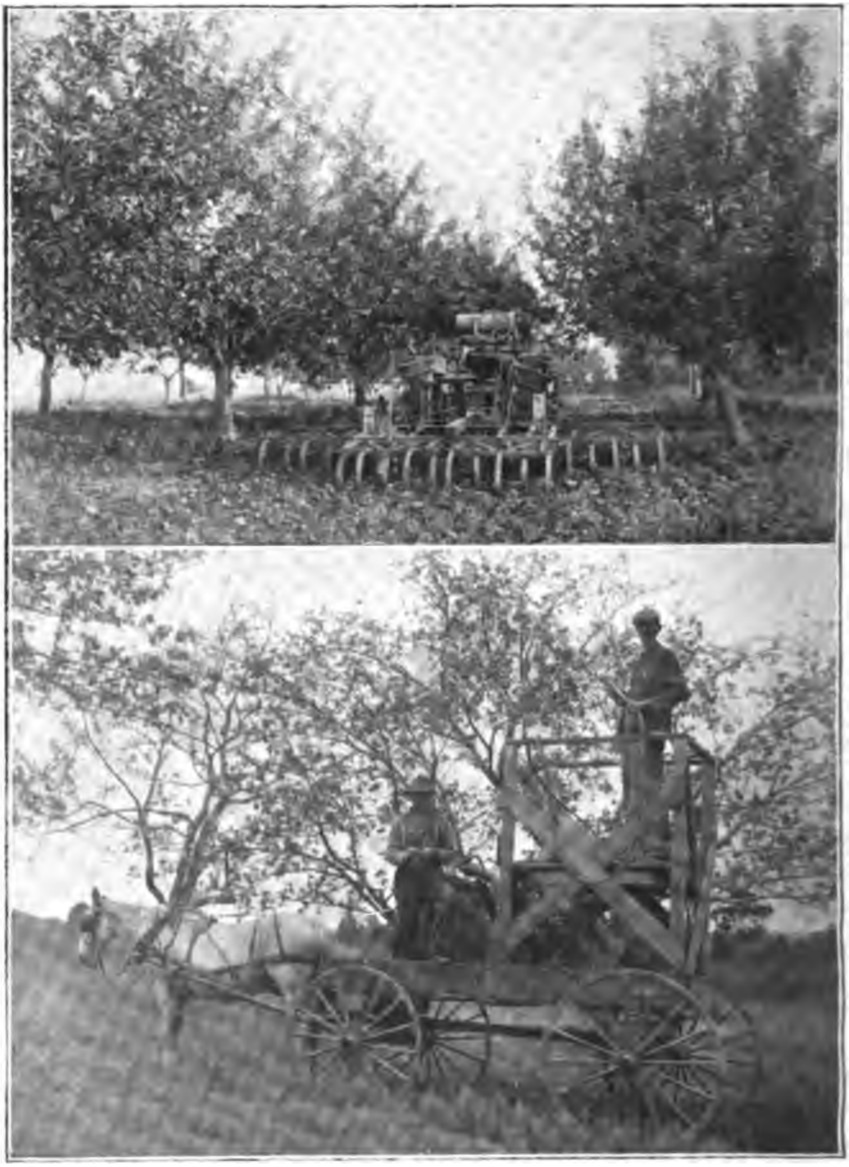


Plate II—Orchard extension harrow drawn by farm tractor. Extensions of the harrow permit low headed trees and clean cultivation near the base of the trunk.

Type of spray outfit used when trees were small—barrel pump, tower platform, single horse, market wagon, a pump and a nozzle man. Power sprayers were used later.

# FIRST 15 YEARS OF A 40-VARIETY APPLE ORCHARD

In 1904 an apple orchard of 40 varieties embracing about two acres was set for the purpose of making a comparative study of the common varieties grown in Vermont. The multiplicity of calls for accurate information based on Vermont conditions evidences the demand for knowledge of the relative behavior of apple trees and their fruit. The demand was urgent in 1904 and still exists.

## THE OBJECTIVE POINTS

The purpose of this project was to secure comparative data touching:

1. Earliness and regularity of bearing.
2. Blossoming dates; duration of bloom with reference to interpollination.
3. Rates of growth in twig and trunk as related to yield.
4. Healthiness and hardiness of varieties with respect to winter injury and the common diseases.
5. Varietal tolerance in storage with instrumental records on humidity and temperature.

## DEVELOPMENT AND CARE OF THE ORCHARD

When the orchard was set out, many sorts were planted; some to be fillers for early crops and some as standards, thus affording many varieties for the comparative study. The standard "long term" trees were placed 40 feet apart and the fillers, the "short term" trees, were set 20 feet apart. It was intended to remove the filler trees between the fifteenth and the twentieth years after setting or as soon as the full space would be required for the standard specimens. A complete list of the varieties employed appears in table I (page 10).

The soil and site need to be described for they are related to the points of inquiry. The best orchard site on the University Farm was chosen, on a knoll gently sloping in all directions except to the south. This site provided excellent drainage for both soil and air, each of which is indispensable, since wet soils are invariably associated with winter injury and poor circulation of air is apt to predispose the trees to spring frost injury or to winter killing. On the other hand sufficient protection against the strong prevailing southwest and northwest winds was secured by a natural windbreak of trees in a line fence.

The soil was a clay loam grading almost to a coarse gravel, with some cobblestones intermixed, deep, moderately rich and in general good tilth. Site and soil were almost ideal, though ill adapted to a few of the many varieties under trial.

## CULTURAL TREATMENT

The orchard was given good care. Nothing extraordinary in this respect was either intended or desired. No effort was made to secure record performances for any such attempt would have defeated the very objects in view. What was considered to be general good care 15 years ago was adopted as the regimen and held to quite rigidly so that there might be a reasonable degree of continuity of treatment throughout the experiment. In order to amplify the phrase "general good care," it seems well to recite the treatment given, since there are different ideas of how best to care for an orchard.

Soil culture, pruning and spraying are the triumvirate of orchard management, the practices which most profoundly influence the trees and control the outcome.

Clean culture with occasional cover crops was employed. The land was plowed in the spring and harrowed at intervals of from 10 to 20 days. This sufficed to suppress weeds and to maintain a good soil mulch. During the earlier years hoed crops, such as Hubbard squash, were grown between the trees. Later on, buckwheat was sown late each July and plowed under the following spring. Red clover replaced buckwheat at regular 5-year intervals, occupying the land during the last half of a summer of one year and the full summer of the following year. The crop was then either cut and placed under the trees as a grass mulch, or was plowed under the succeeding spring as a substitute for manure. Clean culture was generally practiced with clover sod at distant intervals. Neither manure, commercial fertilizers nor lime were used. It was part of the plan from the outset to develop the orchard without expense for fertilization.

Pruning was done annually. The shears and the saw were put to every tree every year. Moderate cutting was done and always during the dormant season. The aim throughout was to keep the tops thin, open and spreading, and to remove small limbs rather than large ones. Wounds were treated with antiseptics as judgment dictated. While this general treatment was given to all trees, a little extra work was done on certain sorts in accordance with varietal needs. In this way a degree of growth uniformity was given to all varieties as well as to all the trees within a variety. Regularity and continuity of treatment were paramount.

Spraying was done in a systematic fashion, using the same spray mixtures each year. Dormant applications of lime and sulfur were made at the rate of 1 to 9 every third year, and more frequently on

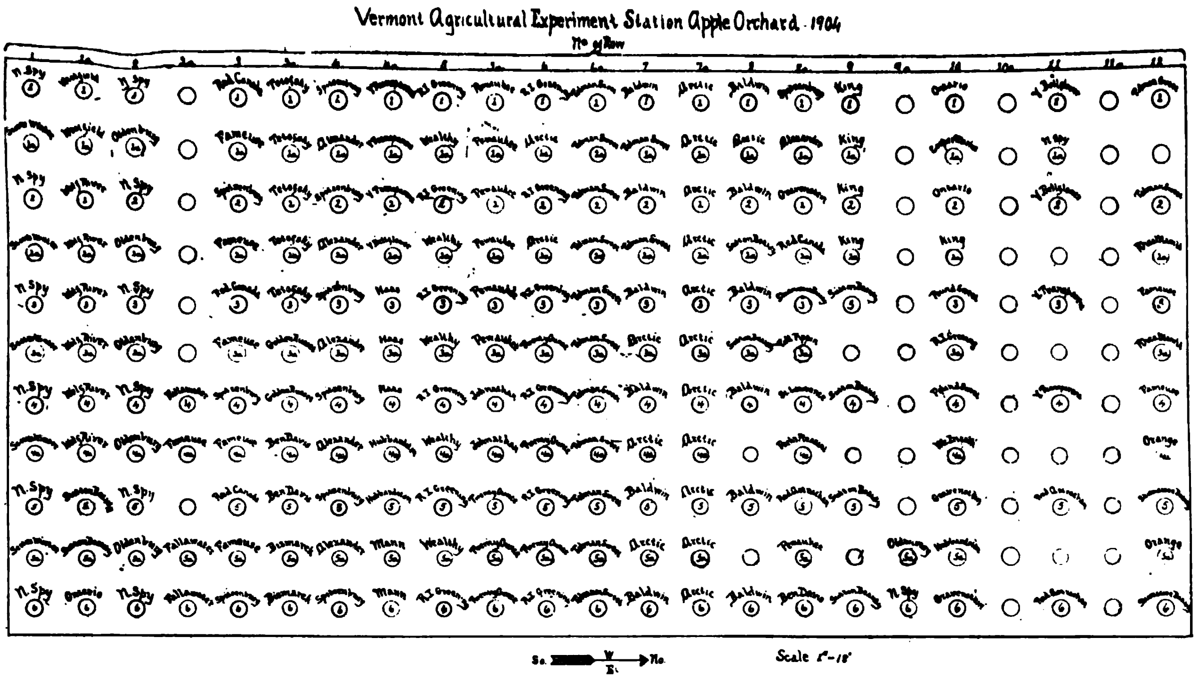


CHART I—General plan of the orchard showing inter-planting plan of using filler and standard trees. At left, row 1, every other tree was a Scott's Winter, a filler; and every other one a Northern Spy, standard. Row 1a, is entirely composed of filler trees, whereas row 2 resembles row 1. Row 9a, 10a, 11a were the dwarf trees which bore early in life but declined early.

certain trees as seemed necessary, for the control of bark louse and blister mite. During the last five years this spray was delayed till the buds were nearly open so to destroy plant lice when they were present.

A before-and-after-blossom spray of lime and sulfur, one gallon to 40 gallons of water, reenforced with 2½ pounds of powdered arsenate of lead, was given each year. This served to control the major pests, such as codling moth, tent caterpillar, apple scab and canker. Only twice during the 15-year period was it necessary in midsummer to make special applications of soap solutions, or "Black Leaf 40," a nicotine sulfate solution, for the control of orchard lice.

It is worth recording in this connection that the orchard has been remarkably free of insect pests and fungus diseases. Timeliness of application and the regularity of the sprayings have served to keep the trees clean and healthy. The importance of this procedure was early recognized because of its relations to yields and to the regularity of crops. It was a bit of good fortune that the spraying could be done during the interim of storms and windy periods, for the spray mixtures were evenly distributed and were completely effective.

## YIELDS OF DIFFERENT VARIETIES

Table I shows the yield of 40 varieties of apples for the first 15 years of the orchard. The points of special interest are those showing the age at which the different varieties began to bear, the average yield for the period and the regularity of the crops.

Four-fifths of the varieties were set in 1904 and the remainder in 1906. Half of them began to bear in 1912 after eight years. Cooper and Northern Spy were the only varieties that were slow in arriving at the fruiting age. The latter is noted for its tardiness in fruiting.

The average yield column is of value in showing the relative numbers of apples the different varieties produced in the period. The most prolific variety was Longfield, which produced 4,927 apples per tree, followed by Yellow Transparent 2,729, Scott 2,601, Oldenburg 2,601, Fameuse 2,598, Yellow Bellflower 2,561.

The six lower yields were: Cooper 62, Gravenstein 118, Roman Stem 165, dwarf Baldwin 207, McIntosh 264, Northern Spy 326. The fourth and fifth ones in this series were not set until 1906, so their period was for only 13 years.

The regularity of crops for any variety is a pertinent matter for the fruit grower. After a tree attains the bearing age, how often does it bear? Is it a successive or an intermittent producer? Many varieties are alternate in this respect. Table I shows the degree of regularity of crops for 40 varieties. The fruiting habit is shown in the two columns entitled "possible crops" and "actual crops" for each kind of tree. The possible crop column includes all trees of each variety for all years since fruit was first produced. The differences between the figures for the actual crops and those for the possible crops show how many failures each variety sustained. For instance, Arctic might have yielded 54 crops from the eight trees for the period from 1912 to 1919 inclusive, each tree each year constituting a possibility after the tree had borne its first crop. As a matter of fact, however, the eight trees bore only 34 crops, there being 20 failures. Different trees failed to fruit in different years. As the table shows, Ben Davis and Maiden Blush fruited every year after beginning. Scott missed but one out of 47 and Fallawater but one out of 22 crops. The most irregular bearers were Baldwin, Rhode Island Greening and Pumpkin Sweet. Some of these irregularities, however, are explained elsewhere—under the heading, "winter injury" (pages 20-21).

For all varieties, including all trees and embracing all years, the possibilities were 1,401 and the actual crops 1,145. In general, then, for the first 8 to 10 crop years the chances are that a tree will bear about 8 years out of 10 years.

The subjoined tables on pages 10 to 12 give the yields for all varieties, and a summary of yields in number and weight of fruits from 1909 to 1919, inclusive, stated alphabetically and the charts II and III on pages 13 and 14 show the data as to yield in terms of numbers and pounds, expressed in the order of yield from lowest to highest.

TABLE I—YIELD OF ALL VARIETIES FOR EACH YEAR

| Variety | Average number of apples per tree | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 |
| Alexander | .. | 8 | ... | 119 | 8 | 208 | ... | 302 | 16 | 540 | 1 |
| Arctic | .. | ... | ... | 27 | ... | 40 | 34 | 134 | 132 | 30 | 38 |
| Baldwin, std. | .. | ... | ... | 9 | 16 | 62 | 24 | 109 | 5 | 8 | 39 |
| Baldwin, dwf. | .. | ... | ... | 2 | ... | 48 | 49 | 74 | ... | ... | 3 |
| Ben Davis | .. | 3 | 37 | 160 | 29 | 214 | 100 | 199 | 25 | 680 | 35 |
| Bismarck | 2 | 34 | 190 | 61 | 239 | 253 | 145 | 185 | 63 | 830 | 31 |
| Boiken | .. | 1 | 113 | 91 | 22 | 265 | 27 | 332 | 21 | 373 | 47 |
| Cooper | .. | ... | ... | ... | ... | ... | ... | ... | 2 | ... | 6 |
| Chenango | 1 | 5 | 59 | 1 | 90 | 40 | 243 | 15 | ... | ... | ... |
| Fallawater | .. | ... | ... | 67 | 8 | 138 | 7 | 205 | 79 | 39 | 22 |
| Fameuse | .. | 1 | 4 | 278 | ... | 300 | 99 | 557 | 134 | 444 | 95 |
| Gravenstein | .. | ... | ... | 25 | ... | 19 | 4 | 69 | 1 | ... | .. |
| Golden Russet | .. | ... | ... | 32 | 7 | 105 | 16 | 152 | 68 | 95 | 28 |
| Haas | .. | 32 | 33 | 133 | 104 | 78 | 158 | 184 | 35 | 619 | 97 |
| Hubbardston | .. | 1 | 6 | 140 | 2 | 98 | 10 | 180 | 130 | ... | .. |
| Jonathan, std. | ... | ... | ... | 320 | 42 | 207 | 6 | 668 | 3 | 145 | 77 |
| Jonathan, dwf. | .. | 3 | ... | 72 | ... | 145 | 20 | 150 | 1 | 51 | 18 |
| King | .. | ... | ... | 24 | 9 | 92 | 5 | 202 | 33 | 3 | 34 |
| Longfield | .. | 12 | 34 | 568 | 8 | 443 | 11 | 266 | 156 | 1,125 | 2,30 |
| Maiden Blush | .. | ... | 13 | 100 | 14 | 87 | 366 | ... | ... | ... | .. |
| Mann | .. | ... | ... | 8 | ... | 53 | 14 | 312 | 11 | 101 | 58 |
| McIntosh | .. | ... | ... | ... | 17 | 14 | 5 | 46 | 34 | 73 | 9 |
| Northern Spy | .. | ... | ... | 2 | ... | 3 | ... | 45 | 22 | 2 | 25 |
| Oldenburg | 1 | 51 | 189 | 227 | 15 | 499 | 3 | 558 | 1 | 922 | 13 |
| Pewaukee | .. | 3 | 11 | 201 | 7 | 93 | 92 | 308 | 19 | 400 | 29 |
| Pumpkin Sweet | .. | ... | 8 | 213 | ... | 123 | 71 | 314 | 112 | 386 | 31 |
| Red Astrachan | .. | ... | 12 | ... | 22 | 232 | 24 | 630 | 13 | 564 | 18 |
| Roman Stem | .. | ... | ... | 25 | ... | 105 | ... | 23 | 12 | ... | .. |
| R. I. Greening | .. | ... | 46 | 170 | 54 | 277 | 20 | 253 | 11 | 16 | 31 |
| Rome | .. | ... | ... | 17 | 15 | 197 | 168 | ... | 39 | 445 | 35 |
| Scott | 3 | 2 | 12 | 165 | 7 | 427 | 47 | 712 | 91 | 511 | 75 |
| E. Spitzenburg | .. | ... | 2 | 14 | 1 | 45 | 20 | 55 | 44 | 36 | 1 |
| Sutton | .. | ... | 3 | 78 | 1 | 123 | 14 | 31 | 339 | 102 | 31 |
| Shiawassee | .. | ... | ... | 16 | 2 | 148 | 10 | 378 | 3 | 465 | 3 |
| St. Lawrence | .. | ... | ... | 150 | ... | 398 | 105 | 599 | 56 | 768 | |
| Tolman | .. | 6 | 24 | 223 | 4 | 256 | 197 | 416 | 46 | 902 | 2 |
| Twenty Ounce | .. | ... | 2 | 40 | ... | 62 | 10 | 79 | 42 | 18 | 1 |
| Wealthy, std. | .. | 5 | 129 | 230 | ... | 445 | 6 | 374 | 3 | 633 | 2 |
| Wealthy, dwf. | .. | ... | ... | 16 | ... | 232 | 53 | 263 | 5 | 487 | 1 |
| Westfield | .. | ... | 54 | 98 | 5 | 211 | 11 | 277 | 62 | 800 | 2 |
| Wolf River | 1 | 1 | 9 | 49 | ... | 30 | 8 | 160 | ... | 519 | |
| Y. Bellflower | .. | 2 | 6 | 13 | ... | 72 | 98 | 408 | 36 | ... | 1,9 |
| Y. Transparent | 5 | 30 | 110 | 186 | 24 | 439 | 1 | 923 | ... | 1,076 | |
| Total | 13 | 200 | 1,106 | 4,370 | 772 | 7,326 | 2,301 | 11,147 | 1,905 | 14,208 | 15,0 |
| Average | ... | 5 | 26 | 102 | 18 | 170 | 53 | 259 | 44 | 330 | 3 |

### TABLE II—CROPS OF APPLES

#### FIRST FIFTEEN YEARS OF ORCHARD

| Variety of apple | First crop came after | Trees in test | Number of apples<br>Total yield | Av. yield per tree | Fruited<br>All trees possible times | Actual crops all years |
|---|---|---|---|---|---|---|
| Alexander | 6 yrs. | 6 | 6,730 | 1,122 | 54 | 34 |
| Arctic | 8 yrs. | 8 | 6,249 | 781 | 56 | 47 |
| Baldwin | 8 yrs. | 5 | 3,134 | 627 | 34 | 27 |
| Baldwin, dwf. | 6 yrs. | 2 | 414 | 207 | 12 | 7 |
| Ben Davis | 6 yrs. | 2 | 3,603 | 1,802 | 19 | 19 |
| Bismarck | 6 yrs. | 2 | 4,059 | 2,030 | 22 | 20 |
| Boiken | 4 yrs. | 2 | 3,441 | 1,721 | 19 | 17 |
| Cooper | 13 yrs. | 1 | 62 | 62 | 3 | 2 |
| Chenango | 4 yrs. | 2 | 902 | 451 | 15 | 13 |
| Fallawater | 7 yrs. | 3 | 2,070 | 690 | 22 | 21 |
| Fameuse | 6 yrs. | 8 | 20,782 | 2,598 | 70 | 60 |
| Gravenstein | 8 yrs. | 1 | 118 | 118 | 8 | 5 |
| Golden Russet | 6 yrs. | 3 | 2,289 | 763 | 23 | 19 |
| Haas | 6 yrs. | 3 | 7,054 | 2,351 | 30 | 27 |
| Hubbardston | 6 yrs. | 2 | 1,132 | 566 | 16 | 14 |
| Jonathan, std. | 8 yrs. | 1 | 2,161 | 2,161 | 8 | 8 |
| Jonathan, dwf. | 4 yrs. | 3 | 1,879 | 626 | 28 | 17 |
| King | 8 yrs. | 3 | 1,783 | 594 | 20 | 18 |
| Longfield | 4 yrs. | 2 | 9,853 | 4,927 | 19 | 16 |
| Maiden Blush | 5 yrs. | 1 | 580 | 580 | 5 | 5 |
| Mann | 8 yrs. | 1 | 1,087 | 1,087 | 8 | 7 |
| McIntosh | 7 yrs. | 5 | 1,319 | 264 | 30 | 25 |
| Northern Spy | 8 yrs. | 10 | 3,264 | 326 | 31 | 25 |
| Oldenburg | 5 yrs. | 2 | 5,203 | 2,602 | 21 | 18 |
| Pewaukee | 6 yrs. | 7 | 9,295 | 1,328 | 58 | 50 |
| Pumpkin Sweet | 7 yrs. | 2 | 3,072 | 1,536 | 17 | 15 |
| Red Astrachan | 6 yrs. | 6 | 10,063 | 1,677 | 50 | 36 |
| Roman Stem | 10 yrs. | 1 | 165 | 165 | 8 | 4 |
| Rome | 8 yrs. | 1 | 1,237 | 1,237 | 8 | 7 |
| R. I. Greening | 5 yrs. | 8 | 9,288 | 1,161 | 69 | 54 |
| Scott | 5 yrs. | 5 | 13,644 | 2,729 | 47 | 46 |
| Spitzenburg | 7 yrs. | 9 | 3,702 | 411 | 69 | 57 |
| Sutton | 7 yrs. | 3 | 3,025 | 1,008 | 25 | 19 |
| Shiawassee | 8 yrs. | 3 | 3,979 | 1,326 | 22 | 17 |
| St. Lawrence | 8 yrs. | 1 | 2,146 | 2,146 | 8 | 7 |
| Tolman | 6 yrs. | 16 | 37,778 | 2,361 | 152 | 138 |
| Twenty Ounce | 8 yrs. | 5 | 2,089 | 418 | 45 | 40 |
| Wealthy, std. | 6 yrs. | 5 | 9,570 | 1,914 | 45 | 36 |
| Wealthy, dwf. | 6 yrs. | 9 | 9,474 | 1,053 | 72 | 52 |
| Westfield | 7 yrs. | 2 | 3,462 | 1,731 | 17 | 15 |
| Wolf River | 5 yrs. | 6 | 5,121 | 854 | 52 | 36 |
| Y. Bellflower | ..... | 1 | 2,561 | 2,561 | 10 | 8 |
| Y. Transparent | ..... | 5 | 13,969 | 2,794 | 54 | 37 |

All varieties were set in 1904, except dwarf Baldwin, Boiken, Chenango, dwarf Jonathan, Longfield, Maiden Blush, McIntosh and dwarf Wealthy, which were set in 1906.

TABLE III—SUMMARY OF YIELDS FOR ALL VARIETIES

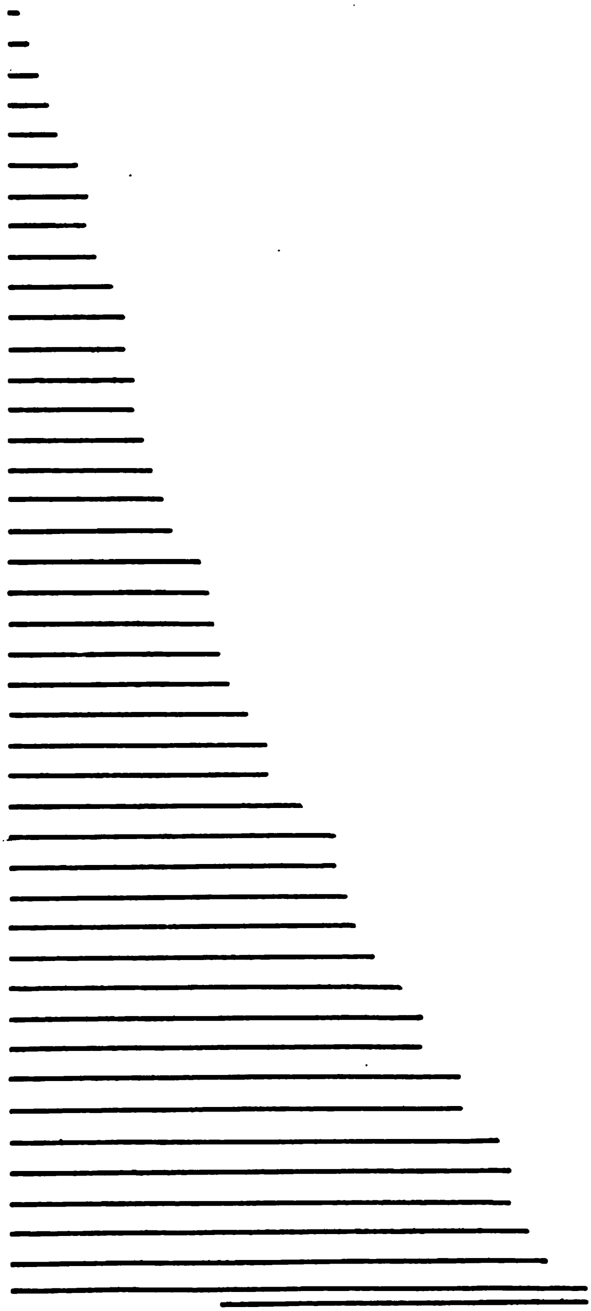
| | | Number of fruits | | | Weight of fruits | | | Number of crop | |
|---|---|---|---|---|---|---|---|---|---|
| Variety | Number trees | Total | Average per tree | Average possible crop per tree | Total pounds | Average per tree, pounds | Average possible crop per tree, pounds | Possible | Actua |
| Alexander | 6 | 6,730 | 1,122 | 125 | 1,999 | 333 | 37 | 54 | 34 |
| Arctic | 8 | 6,249 | 781 | 112 | 1,600 | 200 | 29 | 56 | 47 |
| Baldwin, std. | 5 | 3,134 | 627 | 92 | 984 | 197 | 29 | 34 | 27 |
| Baldwin, dwf. | 2 | 414 | 207 | 35 | 130 | 65 | 11 | 12 | 7 |
| Ben Davis | 2 | 3,603 | 1,802 | 190 | 847 | 424 | 45 | 19 | 19 |
| Bismarck | 2 | 4,059 | 2,030 | 185 | 990 | 495 | 45 | 22 | 20 |
| Boiken | 2 | 3,441 | 1,721 | 181 | 1,115 | 558 | 59 | 19 | 17 |
| Cooper | 1 | 62 | 62 | 21 | 15 | 15 | 5 | 3 | 2 |
| Chenango | 2 | 902 | 451 | 60 | 197 | 99 | 13 | 15 | 13 |
| Fallawater | 3 | 2,070 | 690 | 94 | 749 | 250 | 34 | 22 | 21 |
| Fameuse | 8 | 20,782 | 2,598 | 297 | 4,840 | 605 | 69 | 70 | 60 |
| Gravenstein | 1 | 118 | 118 | 15 | 30 | 30 | 4 | 8 | 5 |
| Golden Russet | 3 | 2,289 | 763 | 100 | 627 | 209 | 27 | 23 | 19 |
| Haas | 3 | 7,054 | 2,351 | 235 | 1,552 | 517 | 52 | 30 | 27 |
| Hubbardston | 2 | 1,132 | 566 | 71 | 377 | 189 | 24 | 16 | 14 |
| Jonathan, std. | 1 | 2,161 | 2,161 | 270 | 445 | 445 | 56 | 8 | 8 |
| Jonathan, dwf. | 3 | 1,879 | 626 | 67 | 387 | 129 | 14 | 28 | 17 |
| King | 3 | 1,783 | 594 | 89 | 619 | 206 | 31 | 20 | 18 |
| Longfield | 2 | 9,853 | 4,927 | 518 | 1,507 | 753 | 79 | 19 | 16 |
| Maiden Blush | 1 | 580 | 580 | 116 | 135 | 135 | 27 | 5 | 5 |
| Mann | 1 | 1,087 | 1,087 | 136 | 260 | 260 | 33 | 8 | 7 |
| McIntosh | 5 | 1,319 | 264 | 44 | 369 | 74 | 12 | 30 | 25 |
| Northern Spy | 10 | 3,264 | 326 | 105 | 1,511 | 151 | 49 | 31 | 25 |
| Oldenburg | 2 | 5,203 | 2,602 | 248 | 1,316 | 658 | 63 | 21 | 18 |
| Pewaukee | 7 | 9,295 | 1,328 | 160 | 2,380 | 340 | 40 | 58 | 50 |
| Pumpkin Sweet | 2 | 3,072 | 1,536 | 181 | 882 | 441 | 52 | 17 | 15 |
| Red Astrachan | 6 | 10,063 | 1,677 | 201 | 2,878 | 480 | 58 | 50 | 36 |
| Roman Stem | 1 | 165 | 165 | 21 | 39 | 39 | 5 | 8 | 4 |
| Rome | 1 | 1,237 | 1,237 | 155 | 278 | 278 | 35 | 8 | 7 |
| R. I. Greening | 8 | 9,288 | 1,161 | 135 | 2,907 | 363 | 42 | 69 | 54 |
| Scott | 5 | 13,644 | 2,729 | 290 | 2,851 | 570 | 61 | 47 | 46 |
| E. Spitzenburg | 9 | 3,702 | 411 | 54 | 1,070 | 119 | 16 | 69 | 57 |
| Sutton | 3 | 3,025 | 1,008 | 121 | 1,041 | 347 | 42 | 25 | 19 |
| Shiawassee | 3 | 3,979 | 1,326 | 181 | 1,337 | 446 | 61 | 22 | 17 |
| St. Lawrence | 1 | 2,146 | 2,146 | 268 | 494 | 494 | 62 | 8 | 7 |
| Tolman | 16 | 37,778 | 2,361 | 249 | 8,689 | 543 | 57 | 152 | 138 |
| Twenty Ounce | 5 | 2,089 | 418 | 46 | 971 | 194 | 22 | 45 | 40 |
| Wealthy, std. | 5 | 9,570 | 1,914 | 213 | 2,230 | 446 | 50 | 45 | 36 |
| Wealthy, dwf. | 9 | 9,474 | 1,053 | 132 | 2,207 | 245 | 31 | 72 | 52 |
| Westfield | 2 | 3,462 | 1,731 | 204 | 759 | 380 | 45 | 17 | 15 |
| Wolf River | 6 | 5,121 | 854 | 99 | 1,972 | 329 | 38 | 52 | 36 |
| Y. Bellflower | 1 | 2,561 | 2,561 | 256 | 827 | 827 | 83 | 10 | 8 |
| Y. Transparent | 5 | 13,969 | 2,794 | 259 | 4,271 | 854 | 79 | 54 | 37 |
| Total all varieties | 173 | 232,808 | 57,466 | 6,631 | 60,684 | 14,732 | 1,726 | 1,401 | 1,145 |
| Average | 4 | 5,414 | 1,136 | 154 | 1,411 | 343 | 40 | 33 | 27 |

## Relative Productivity in Number of Apples

### First Fifteen Years of Variety Orchard—Average per Tree

Scale:—1 in. = 1,000 apples

| | |
|---|---|
| Cooper | 62 |
| Gravenstein | 118 |
| Roman Stem | 165 |
| Baldwin, dwf. | 207 |
| McIntosh | 264 |
| Northern Spy | 326 |
| Spitzenburg | 411 |
| Twenty Ounce | 418 |
| Chenango | 451 |
| Hubbardston | 566 |
| Maiden Blush | 580 |
| King | 594 |
| Jonathan, dwf. | 626 |
| Baldwin | 627 |
| Fallawater | 690 |
| Golden Russet | 763 |
| Arctic | 781 |
| Wolf River | 854 |
| Sutton | 1,008 |
| Wealthy, dwf. | 1,053 |
| Mann | 1,087 |
| Alexander | 1,122 |
| R. I. Greening | 1,161 |
| Rome | 1,237 |
| Shiawassee | 1,326 |
| Pewaukee | 1,328 |
| Pumpkin Sweet | 1,536 |
| Red Astrachan | 1,677 |
| Bolken | 1,721 |
| Westfield | 1,731 |
| Ben Davis | 1,802 |
| Wealthy | 1,914 |
| Bismarck | 2,030 |
| St. Lawrence | 2,146 |
| Jonathan | 2,161 |
| Haas | 2,351 |
| Tolman | 2,361 |
| Y. Bellflower | 2,561 |
| Fameuse | 2,598 |
| Oldenburg | 2,602 |
| Scott | 2,729 |
| Y. Transparent | 2,794 |
| Longfield | 4,927 |



### RELATIVE PRODUCTION IN POUNDS

FIRST FIFTEEN YEARS OF VARIETY ORCHARD—AVERAGE PER TREE

Scale:—1 in. = 300 lb.s

| | |
|---|---|
| **Cooper** | **15** |
| **Gravenstein** | **30** |
| **Roman Stem** | **39** |
| **Baldwin, dwf.** | **65** |
| **McIntosh** | **74** |
| **Chenango** | **99** |
| **Spitzenburg** | **119** |
| **Jonathan, dwf.** | **129** |
| **Maiden Blush** | **135** |
| **Northern Spy** | **151** |
| **Hubbardston** | **189** |
| **Twenty Ounce** | **194** |
| **Baldwin** | **197** |
| **Arctic** | **200** |
| **King** | **206** |
| **Golden Russet** | **209** |
| **Wealthy, dwf.** | **245** |
| **Fallawater** | **250** |
| **Mann** | **260** |
| **Rome** | **278** |
| **Wolf River** | **329** |
| **Alexander** | **333** |
| **Pewaukee** | **340** |
| **Sutton** | **347** |
| **R. I. Greening** | **363** |
| **Westfield** | **380** |
| **Ben Davis** | **424** |
| **Pumpkin Sweet** | **441** |
| **Jonathan** | **445** |
| **Shiawassee** | **446** |
| **Wealthy, std.** | **446** |
| **Red Astrachan** | **480** |
| **St. Lawrence** | **494** |
| **Bismarck** | **495** |
| **Haas** | **517** |
| **Tolman** | **543** |
| **Boiken** | **558** |
| **Scott** | **570** |
| **Fameuse** | **605** |
| **Oldenburg** | **658** |
| **Longfield** | **753** |
| **Y. Bellflower** | **827** |
| **Y. Transparent** | **854** |

## RELATIVE BLOSSOMING PERIODS

A study was made of the relative blossoming periods of 38 varieties for six years. The blossoming dates for the seasons under observation have been averaged and are arranged in the order of early blossoming. Longfield blossoms first, as it averaged to begin on May 14; Fameuse, Tolman and Northern Spy were late, for they did not average to blossom until May 18. The dates for the first and last blooms, representing the beginning and the ending of the period of open blossoms, were for the first and last dozen blossoms, the full bloom period being approximately the mean of the two extremes.

The length of the blossoming period for any variety is a matter of some economic importance. Good weather at blossoming time is imperative. Cold storms occasionally happen in Vermont in the middle of May when orchards are in full bloom. Unfavorable weather at this time often spells disaster, for insects can scarcely work among the blossoms under these conditions and the flowers are not well pollinated or completely fertilized.

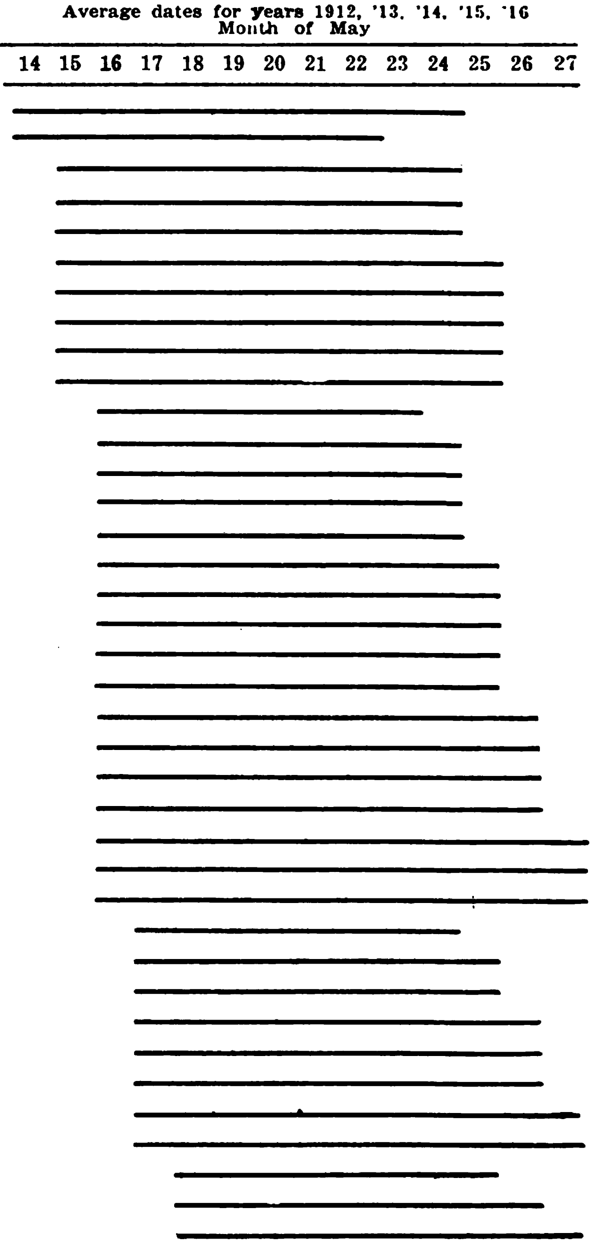
The U. S. Weather Bureau records disclose the relationship between good and poor weather and long and short blossoming periods. In 1912 a 1.7 inch rainfall occurred during the first part of the blossoming period. The early blooming varieties were exposed to it but the late ones nearly escaped it. In 1913 no rain fell until nearly the end of the blossoming time, and then only 0.3 inch came. In 1914 very little rain fell at the critical time, 0.01 inch during the early and 0.07 inch during the latter portion of the period. In 1915 a rainfall of 0.48 inch occurred during the middle of the blossoming period and yet more at its close. In 1916, 0.25 inch fell early but scarcely any fell later on. In 1919 most of the rainfall happened in the forepart of the blossoming season, with lighter showers up to the middle of the period. Some of the early and some short-time blossoming varieties experienced but little good weather during the blossoming period, while the 12-day varieties had plenty of sunshine.

Chart IV shows that the average blossoming period of 38 varieties of apples varies from 8 days for sorts like Red Astrachan, Sutton and Fameuse to 12 days for varieties like Bismarck, Fallawater and Rhode Island Greening. Four more days of bloom in certain years, either before or after a storm, might result in the simple and significant difference between a good crop and a poor one, as determined by the length of the blossoming period of a variety. The variety with a long blossoming season has a better chance to escape storm and bear

## CHART IV

### RELATIVE BLOSSOMING PERIOD

| Variety | Days of bloom |
|---|---|
| Longfield | 11 |
| Red Astrachan | 8 |
| King | 10 |
| Pumpkin Sweet | 10 |
| Scott | 10 |
| Boiken | 11 |
| Gravenstein | 11 |
| Haas | 11 |
| Pewaukee | 11 |
| Rome | 11 |
| Tetofsky | 8 |
| Maiden Blush | 9 |
| Oldenburg | 9 |
| Shiawassee | 9 |
| Twenty Ounce | 9 |
| Alexander | 10 |
| Baldwin | 10 |
| Chenango | 10 |
| Golden Russet | 10 |
| McIntosh | 10 |
| Jonathan | 11 |
| Wealthy | 11 |
| Y. Bellflower | 11 |
| Y. Transparent | 11 |
| Bismarck | 12 |
| Fallawater | 12 |
| R. I. Greening | 12 |
| Sutton | 8 |
| Arctic | 9 |
| Wolf River | 9 |
| Ben Davis | 10 |
| Hubbardston | 10 |
| St. Lawrence | 10 |
| Spitzenburg | 11 |
| Westfield | 11 |
| Fameuse | 8 |
| Tolman | 9 |
| Northern Spy | 10 |



regularly then has a short one. If one turns to the table of crops, it is seen that Rhode Island Greening bore 54 times in a possible of 69; Fallawater, 21 out of 22; and Bismarck, 20 out of 21. Treating the 12-day blossoming lots as a unit, the actual crops in relation to possible ones were 95 to 112, or a skip of 17. On the other hand, there were the 8-day blossoming varieties such as Fameuse, which bore 60 out of 70 times; Sutton, 20 out of 22; and Red Astrachan, 36 out of 50 times; and, combining these as a unit, the actual crops as compared with possible ones were 116 out of 142, or a skip of 26 crops. A long blossoming variety possesses some advantages in relation to weather over those blossoming for a short time only.

In studying the chart it is seen that most varieties overlap so well in blossoming dates that interpollination is possible if good weather prevails and the necessary insect are present and actively at work.

### GROWTH OF DIFFERENT VARIETIES

The growth which a variety makes may be a measure of its adaptation to a certain locality and, also, a gauge of the effect of the cultural treatment which it receives. The size of the trunk is related to the crop produced. Tables IV and V present the data touching these matters.

The measurements of twig growth were begun in 1904, continued until 1910, and made again in 1918 and 1919. The average rate of growth for all trees in each variety is given in inches, together with the average for all the varieties.

Certain varieties may be said to be fast growers and others slow growers. The twigs of Arctic and McIntosh, 19, Rome and Haas, 23, and Northern Spy, Wolf River and Spitzenburg, 20 inches each, grew relatively rapidly, while Shiawassee, 14, Bismarck, 15, Astrachan and Fallawater, 16, and Rhode Island Greening and Longfield, 17, Westfield, 16, grew relatively slowly. The average twig growth for all varieties was about 18 inches, a quite sufficient amount.

The average twig growth for all varieties during the initial year, 1904, was rather small, being only 15 inches; during the next five years, however, it was 22½ inches; while in 1918 and in 1919, when the trees were 14 and 15 years old, the average linear twig growth was only 7 inches. It is clear, therefore, that the twig growth varied with the age of the tree as well as with the conditions of culture.

The purpose in presenting these data is not merely to show how varieties may differ in the amount of twig growth when handled under similar conditions but to show the average growth under definite and prescribed conditions of culture carried on during a series of years. Greater linear growth might have been secured had fertilizers been used, but it does not appear that greater growth would have been beneficial.

The average horizontal spread of limbs at the plane of the maximum distance was taken for head diameter. The average for all varieties was 17 feet. The extent to which any variety departs from the average as shown in the table seems to indicate the shape which a variety will take, a disposition which it is well to recognize in all pruning work.

The diameter of the trunk is probably a more correct means of comparing the growth of different varieties, or of the trees of the same variety under different conditions of culture than is linear twig growth. The diameters were ascertained by the use of calipers, the measurements being made half way between the ground and the origin of the scaffold limbs. The tables show that Boiken, Cooper, Bismarck, Oldenburg, Twenty Ounce, and Wealthy represent the trees with relatively small diameters, whereas Fallawater, Yellow Bellflower, Fameuse, Haas, Rome and St. Lawrence possessed relatively large diameters. The average trunk diameter for all trees of all varieties was 6.4 inches

The trees with relatively large trunks give on the whole larger yields than those with smaller trunks. If one groups all the varieties, the trunk diameters of which exceed an average of 6.4 inches, the average number of apples produced is 1,931, whereas the medial yield is 1,468 for those trees with trunk diameters below this average, a difference of 473 or an increase of approximately one-third

A more reliable comparison may be made as to the relation between trunk diameters and yields by citing cases among individual trees of certain varieties. For example: Among 16 Tolman trees there was one with a trunk of only 3 inches in diameter. Its total yield was 92 apples. The largest Tolman trunk diameter was 8.3 inches, and that tree carried 3,475 apples, which was almost the largest yield among the 16 trees. Among 7 Rhode Island Greenings, the two smaller ones (trunk diameter of 5.2 inches) averaged 276 apples, while the largest tree with a diameter of 7.8 inches gave a yield of 1,075 apples. Among 5 Scott trees, that with the largest trunk—7.2 inches in diameter—yielded 3,762 apples, while that with a small trunk—5.7 inches—yielded 2,840 apples. Among 7 Fameuse, the largest trunk diameter of 7.7 inches was associated with a total yield of 3,655, but the smallest trunk diameter, 6.3 inches, with a total yield of 2,566. The small diameter Red Astrachans—3.6 inches—produced a total yield of 770 apples, whereas the large diameter trees—9 inches—produced a yield of 3,582 apples.

There would seem to be a relation between the size of the trunk and the size of the crop. It is natural to infer that the former is a prerequisite to the latter.

### Table IV—Growth Measurements

AVERAGE GROWTH PER TREE

| Variety | Length of twig growth | Diameter of trunk | Diameter of head | Height of tree | Number of main limbs | Average number of apples per tree |
|---|---|---|---|---|---|---|
| | inches | inches | feet | feet | | |
| **Arctic** | 19 | 6.8 | 20 | 14 | 4.6 | 781 |
| **Alexander** | 16 | 5.8 | 17 | 12 | 4.3 | 1,122 |
| **Ben Davis** | 18 | 5.2 | 15 | 12 | 4.3 | 1,802 |
| **Bismarck** | 15 | 4.2 | 13 | 10 | 4.0 | 2,030 |
| **Boiken** | 17 | 5.8 | 16 | 10 | 3.5 | 1,721 |
| **Cooper** | 18 | 5.6 | 17 | 13 | 3.0 | 62 |
| **Fallawater** | 16 | 7.6 | 16 | 11 | 4.0 | 690 |
| **Fameuse** | 18 | 7.0 | 20 | 13 | 4.4 | 2,598 |
| **Golden Russet** | 17 | 6.1 | 17 | 13 | 4.0 | 763 |
| **Haas** | 23 | 7.2 | 20 | 15 | 5.0 | 2,351 |
| **King** | 18 | 6.9 | 10 | 13 | 4.0 | 594 |
| **Longfield** | 17 | 5.8 | 16 | 10 | 3.0 | 4,927 |
| **Mann** | 18 | 6.8 | 20 | 14 | 5.0 | 1,087 |
| **McIntosh** | 19 | 6.6 | 10 | 11 | 4.5 | 264 |
| **Northern Spy** | 20 | 5.7 | 16 | 13 | 4.1 | 326 |
| **Oldenburg** | 17 | 5.5 | 17 | 13 | 4.5 | 2,602 |
| **Pewaukee** | 17 | 6.8 | 16 | 12 | 5.4 | 1,328 |
| **Pumpkin Sweet** | 19 | 6.7 | 19 | 13 | 5.0 | 1,536 |
| **Red Astrachan** | 16 | 6.2 | 15 | 12 | 4.2 | 1,677 |
| **Rome** | 23 | 7.5 | 19 | 15 | .. | 1,237 |
| **R. I. Greening** | 17 | 6.8 | 16 | 12 | 4.3 | 1,161 |
| **Scott** | 17 | 6.4 | 16 | 12 | 3.2 | 2,729 |
| **Spitzenburg** | 20 | 5.5 | 16 | 11 | 4.6 | 411 |
| **Sutton** | 17 | 6.5 | 18 | 13 | 4.0 | 1,008 |
| **Shiawassee** | 14 | 5.3 | 17 | 11 | 4.3 | 1,326 |
| **St. Lawrence** | 18 | 7.7 | 19 | 13 | 5.0 | 2,146 |
| **Tolman** | 17 | 6.8 | 18 | 11 | 4.7 | 2,361 |
| **Twenty Ounce** | 16 | 5.1 | 14 | 12 | 3.8 | 418 |
| **Wealthy** | 19 | 5.2 | 15 | 11 | 5.3 | 1,914 |
| **Westfield** | 16 | 6.7 | 14 | 12 | 3.5 | 1,731 |
| **Wolf River** | 20 | 6.1 | 18 | 11 | 3.5 | 854 |
| **Y. Transparent** | 19 | 6.1 | 17 | 13 | 4.5 | 2,794 |
| **Y. Bellflower** | 18 | 9.0 | 20 | 14 | 6.0 | 2,561 |
| **Total** | 589 | 209.0 | 547 | 405 | 137.5 | 50,912 |
| **Average** | 18 | 6.4 | 17 | 12 | 4.3 | 1,543 |

A few varieties used in the yield data elsewhere were not employed in the growth data on account of winter injury or because such trees were devoted to other work. Standard trees only were used in growth data.

TABLE V—AVERAGE RELATIVE GROWTH OF NEW WOOD FOR EIGHT YEARS

AVERAGE LENGTH IN INCHES

| Varieties and trees of each | | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1918 | 1919 | Total | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic | 6 | 10 | 32 | 29 | 19 | 25 | 25 | 8 | 7 | 155 | 19 |
| Alexander | 6 | 16 | 24 | 28 | 14 | 19 | 15 | 8 | 5 | 129 | 16 |
| Ben Davis | 3 | 19 | 23 | 24 | 11 | 20 | 16 | 7 | 6 | 126 | 18 |
| Bismarck | 2 | 12 | 18 | 28 | 11 | 17 | 19 | 5 | 6 | 116 | 15 |
| Boiken | 2 | .. | .. | 24 | 20 | 24 | 21 | 7 | 3 | 99 | 17 |
| Chenango | 2 | .. | .. | 30 | 23 | 24 | 22 | .. | .. | 99 | 25 |
| Cooper | 1 | 18 | 29 | 26 | 9 | 23 | 21 | 9 | 9 | 144 | 18 |
| Fallawater | 3 | 7 | 21 | 29 | 15 | 20 | 27 | 7 | 5 | 131 | 16 |
| Fameuse | 8 | 11 | 22 | 26 | 18 | 24 | 25 | 9 | 8 | 143 | 18 |
| Golden Russet | 2 | 19 | 27 | 26 | 19 | 19 | 26 | 10 | 8 | 154 | 19 |
| Haas | 3 | 24 | 35 | 35 | 24 | 29 | 26 | 8 | 5 | 186 | 23 |
| King | 4 | 12 | 30 | 26 | 16 | 22 | 25 | 6 | 8 | 145 | 18 |
| Longfield | 2 | .. | .. | 18 | 23 | 25 | 22 | 7 | 5 | 100 | 17 |
| Mann | 2 | 13 | 26 | 25 | 18 | 23 | 24 | 9 | 7 | 145 | 18 |
| McIntosh | 4 | .. | .. | 29 | 18 | 18 | 25 | 10 | 12 | 112 | 19 |
| Northern Spy | 12 | 18 | 30 | 26 | 20 | 24 | 26 | 9 | 8 | 161 | 20 |
| Oldenburg | 2 | 13 | 26 | 27 | 17 | 19 | 21 | 7 | 7 | 137 | 17 |
| Pewaukee | 7 | 14 | 28 | 26 | 14 | 18 | 22 | 6 | 5 | 133 | 17 |
| Pound Sweet | 2 | 21 | 31 | 24 | 19 | 21 | 22 | 8 | 2 | 148 | 19 |
| Red Astrachan | 6 | 13 | 26 | 27 | 16 | 19 | 19 | 7 | 6 | 133 | 17 |
| Rome | 1 | 2 | 34 | 34 | 18 | 28 | 20 | .. | .. | 136 | 23 |
| R. I. Greening | 12 | 13 | 28 | 26 | 12 | 22 | 23 | 6 | 6 | 135 | 17 |
| Scott | 5 | 18 | 24 | 21 | 15 | 21 | 23 | 9 | 7 | 138 | 17 |
| Spitzenburg | 9 | 13 | 28 | 34 | 18 | 24 | 26 | 9 | 8 | 160 | 20 |
| Sutton | 4 | 14 | 22 | 28 | 14 | 18 | 22 | 9 | 6 | 133 | 17 |
| Shiawassee | 3 | 15 | 19 | 16 | 14 | 12 | 18 | 7 | 7 | 108 | 14 |
| St. Lawrence | 1 | 20 | 28 | 27 | 19 | 16 | 22 | 8 | 6 | 146 | 18 |
| Tolman | 14 | 14 | 28 | 27 | 12 | 20 | 21 | 8 | 4 | 134 | 17 |
| Twenty Ounce | 5 | 14 | 24 | 23 | 9 | 18 | 23 | 10 | 6 | 127 | 16 |
| Wealthy | 5 | 13 | 26 | 30 | 20 | 23 | 23 | 8 | 5 | 148 | 19 |
| Westfield | 2 | 14 | 23 | 21 | 12 | 19 | 23 | 6 | 7 | 125 | 16 |
| Wolf River | 6 | 21 | 28 | 27 | 19 | 25 | 22 | 9 | 7 | 158 | 20 |
| Y. Bellflower | 1 | 17 | 23 | 24 | 20 | 26 | 20 | 7 | 8 | 145 | 18 |
| Y. Transparent | 5 | 17 | 27 | 29 | 20 | 21 | 23 | 7 | 4 | 148 | 19 |
| Average | .. | 15 | 26 | 26 | 17 | 21 | 22 | 8 | 6 | ... | .. |

## WINTER INJURY AND VARIETAL RESISTANCE

The ability of any variety to withstand severe winters is a fundamental consideration. Winter endurance is not a new but a recurring problem. In view of the longevity of an orchard, the succession of varieties and the frequent introduction of new sorts, it is obvious that winter tolerance is always to be borne in mind in selecting varieties. Such varieties as Winter Banana, Delicious, Opalescent and North Western Greening were not known to Vermonters, or at least were not grown here in 1904, when the station variety orchard was planted. It takes time to study varietal adaptations. The trees must be grown to bearing age and a considerable period of years must elapse before one can measure merits or demerits Extremes of climate, especially such severe winters as test the very limits of resistance, seem to come periodically, and they must be reckoned with in Vermont in apple culture as they must be in Florida in citrus culture. Six especially severe winters have occurred during the past 16 years in Vermont, the more recent ones 13 and 14 years after the station orchard was set. These afforded a real test of the effect of frigid weather upon these 40 varieties of apple trees. Most of the trees had begun to bear, some were bearing heavily for their age, and all were due to bear the next year. The effect of temperatures ranging from —20° to —28° F. continued for a protracted period, upon the health of the trees and on the succeeding crop were points open to observation.

The local U. S. Weather Bureau Station is located within 500 feet of and only a few feet lower than the station orchard. Its records indicate the following temperatures:

1908, February 5, —27°, wind east, 2 to 7 miles per hour;
1912, January 26, —24°, wind east, 4 to 9 miles per hour;
1914, January 14, —26°, wind east, 5 to 9 miles per hour;
1917, February 12, —18°, wind north-east, 2 to 12 miles per hour;
1917, December 30, —25°, wind east, from 3 to 10 miles per hour;
1919, January 10, —11°, wind 7 miles per hour, later increasing to 44 miles;
1920, February 1, —28°, wind 6 to 9 miles per hour, later changing to 48 miles.

The lowest temperature occurring since the orchard was set was —28° F. on February 1, 1920. This held only for a short time. Practically no winter injury resulted. Most of the winter injury in the orchard occurred during the winter of 1917-18. Much lower temperatures were unofficially reported from other parts of the State. Such low records as are given above, if accompanied with a wind of high velocity, and if protracted, would surely result disastrously. Cold air is usually dry, and continued cold winds hasten evaporation and induce desiccation, which is at least one important factor in winter killing. It should be recognized in this connection that the condition of the soil, the slope or aspect of the land in relation to strong winds and windbreaks, as well as the condition of the trees at the approach of winter weather, are important factors in effecting harm or protecting the orchard. The effect of these factors was manifested in different parts of the State during the severe 1917-1918 winter, Baldwins in some places being killed outright while remaining unharmed in other localities. The experimental orchard had been under clean cultivation during the summers preceding the cold winters. Harrowing was discontinued, however, in early August, and the land left unstirred during the rest of the season, so that the trees might cease growth, ripen their wood, and harden and toughen their tissues in preparation for winter vicissitudes. To all appearances these ends were secured and the trees appeared to be in good condition to pass the winter. Fall and early winter weather in Burlington were favorable for the trees.

Winter injury is diversely manifested. Extreme cold weather may cause longitudinal cracks in the trunk, crotch canker, dead buds or twigs, the partial or complete death of limbs or the death of the entire tree after an interval of some weeks or months. Most of these results occurred with the varieties that showed winter injury.

Baldwin, King, Fallawater and Spitzenburg were most severely injured. Five Baldwin trees were scattered through the orchard, according to the planting plan, hence the condition or nature of the soil in any one spot could hardly have been the cause of injury, or have predisposed the variety to winter killing because of location. No one of the trees was killed outright or so injured that death ensued at a later time; but three were removed in 1919, badly injured, with several dead limbs and some dead areas on the scaffold limbs and trunks. The fourth tree was in bad shape, a year later, though far from being dead. The fifth tree was unharmed, sound, healthy and bearing in 1920. Baldwins suffered severely in Grand Isle County, whereas in Addison County, for the most part, they were not hurt. Differences in cultural and soil conditions undoubtedly account for this seeming discrepancy.

The two King trees suffered severely. They were centrally located in the orchard and were in good condition in the fall of 1917. Despite the small numbers, the circumstances attending their injury and early death were such as to leave no doubt in the writer's mind as to their inability to withstand such low temperatures under the conditions prevailing in Burlington during the winters of 1916 to 1918, inclusive.

The six Spitzenburg trees were badly injured. They were planted in different areas in the orchard and under slightly different soil, structural and cultural conditions but, notwithstanding, the injuries were quite uniform. Despite two years of good care they were unable to recover.

The Sutton and Twenty Ounce trees were injured beyond recovery. Not a single tree of either variety was worth retaining in the orchard after 1919, except in order to ascertain the final effect of winter injury, which was disastrous.

Fallawater and Rhode Island Greening did not show decisive results. There were four Fallawater trees in the orchard, but only two of them were in the 15-year experiment. The two in the trial were injured quite severely but not killed, while the other two trees, growing near by, were absolutely unharmed. The Rhode Island Greening trees showed different degrees of injury. Two trees were badly hurt, two others showed crotch injury which, later, developed into controllable cankers, while the remainder were unharmed. Some of these were small trees, and some were pedigree plants and not in the experiment, but all were within the orchard area and subjected to the same cultural treatment.

The Northern Spy trees were not injured. In some parts of the State both large and small trees of this variety were reported as being badly injured.

In view of the lack of resistance to such severe weather as occurred in 1917-18 and 1918-19, and since such temperatures may recur at more or less frequent intervals, it is the writer's opinion that it is unsafe to plant such varieties as are shown by this experiment to have sustained serious injury in locations analogous to that on which the station orchard was placed.

The other 33 varieties listed elsewhere in tables I and VIII (pages 10 and 32) on yields and storage were uninjured during these severe winters. It is remarkable not that a few died but, rather, that so many survived, and that so many apple trees of different varieties were able to endure a winter temperature of —28° and remain unimpaired as to fruit production. Conditions of soil or location may exist or of hardiness of stock, for instance, where the Baldwin or some other varieties may be successfully grown, but if so such in all probability should be viewed as exceptions to the rule.

As a result of a survey of winter injury throughout the State, the following statement was made by the writer in November, 1918, before the annual meeting of the Vermont State Horticultural Society:

"Winter injury to fruit trees in Vermont during the season of 1917-18 was quite extensive throughout the State, although the earlier reports seemed to indicate that greater harm had been done than had really been the case. Newspaper reports are often exaggerated. However, the surprising thing is not that there was some injury, but that there was not more than actually occurred. As far as can be ascertained the injury was about the same in various parts of the State in proportion to the number of trees in the respective areas. The varieties that were most severely injured were the Baldwin, Ben Davis, Pewaukee, Spitzenburg and Northern Spy. Recent plantings in a few instances of McIntosh and Northern Spy were also seriously injured.

"In a few instances small trees were seriously injured, due primarily to the recent setting and, perhaps, to the inability of the roots to become firmly established in the subsoil. In many places the trees were most injured which bore heavily in the season of 1917. A possible explanation is that the trees were somewhat exhausted and that food needed for recovery was consumed in maturing a crop the preceding season.

"In other cases the injury to such varieties as Spitzenburg, Pewaukee and Ben Davis was thought to be due to the late rains which were accompanied by warm weather, factors which hindered the trees from becoming toughened and hardened for winter. Whenever trees go into the winter in an immature condition there is likely to be winter injury even though the temperatures are not unusually severe.

"In other cases the winter injury was only temporary, in which cases it affected the twigs and buds. In the case of the Northern Spy it is reported that there was scarcely a crop anywhere in New England in 1918 but there were very few cases reported where the trees were entirely killed.

"In other instances the winter injury was greatest in exposed places, or where trees were set in rather shallow soil. Cold air is dry, and, unless the trees can get water from the soil to make good the loss by evaporation, the death of live tissue is likely to ensue.

"In many cases the greatest injury was among cider apple trees, already weakened by insect injuries and sick with canker. Such neglected trees naturally succumb to severe winter weather. It will be a blessing to get rid of these old trees, for they are a menace."

Reports as to resistance and tolerance of varieties in different parts of the State were discordant. Some reported injury to Rhode Island Greenings, others none at all; some found Ben Davis very susceptible, although it was perfectly hardy at the Station; in other places not far from Burlington, the Baldwin was not injured. Reports of this nature were to be expected, for diverse conditions of culture or soil or of weather might explain the different results.

It is worth recording in connection with the study of winter tolerance that two of the newer varieties, Winter Banana and Delicious, were reported as uninjured, or only slightly so, even when grown as far north and east as Danville, and as far north and west as Grand Isle, escaping the havoc wrought to many other sorts in those sections during the cold waves.

The possibility of winter injury must always be one of the gravest risks of the fruit grower. Winter weather of great severity is beyond control. Aside from selecting hardy varieties, and choosing sites with due attention to local protection, there are certain matters which should be borne in mind in orchard operations in Vermont. They may be listed as follows:

1. Late summer or fall plowing, harrowing and fertilizing tend to encourage late growth and to hinder the ripening and maturing of woody tissue, especially of the buds and twigs.
2. Poor drainage induces winter injury. Wet lands, like late culture, delay the ripening of tissues.
3. Low areas with poor air drainage are subject to winter injury. Hillside orchards are conspicuously free from winter injury.
4. Midsummer cover crops that use food and moisture, diverting it from the trees, tend to lessen injury since they hasten dormancy of buds and twigs.

The character, in detail, of winter injury is still somewhat obscure and exhibits several phases. It may be due to the withdrawal of so much moisture from the twigs that death of the tissues ensues by desiccation, the drying out of live cells. Cold air is dry and cold waves are windy ones. The twigs lose moisture beyond their ability to recover. In other cases the injury takes the form of frost cracks due to the freezing and expansion of tissue water. In still other cases death results from absolute low temperature which certain plants, or varieties, cannot withstand.

The treatment of winter injured trees depends on the degree of injury, extermination for dead trees, moderate pruning for trees with *only* local injuries, since dead limbs are not only useless but detrimental and, finally, immediate and general good care in the spring and summer.

With respect to the avoidance of winter injury it is suggested:

1. That more attention be given to hardy varieties.
2. That better air and soil drainage be secured, choosing high rather than low areas for orchards.

3. That all late summer cultural practices that stimulate and induce late growth and hinder the maturity of buds and twigs be discontinued.

## TOLERANCE IN STORAGE

Storage tests were conducted with 36 varieties during three seasons: 1916-17, 1917-18 and 1919-20. The main object of the tests was to ascertain the comparative endurance of different varieties under recorded conditions of temperature and humidity. Seven-day thermograph and hygrograph instruments were installed in the storage room which recorded dial readings every two hours from late August of one year until early August of the next season.

The storage room was located in a concrete basement, such as many farmers possess or may construct. The conditions of humidity and temperature were under close control. No attempt was made to produce or to maintain warehouse conditions. No artificial cooling was provided or desired. The room was dark, moist and cool most of the time. A humid atmosphere was secured and maintained by means of exposed surfaces of water in tubs or by sprinkling water on the concrete cellar bottom. The humidity designedly was kept relatively high, but the temperature was kept low most of the time by means of ventilation with windows near the ground and by their closure during warm days, especially in the fall and again in the spring. In the severe midwinter weather, protection against freezing was secured by the use of oil stoves. Harmful thermometric extremes were thus avoided. Winter temperatures were never too low, although summer temperatures were often too high for the maximum preservation; but these extremes are factors which any farmer will encounter in his own storage operations. Obviously the conditions in the storage room approximated those found on many Vermont farms.

Much care was exercised in handling the fruit. The specimens used for storage trials were carefully removed from the trees at nearly if not quite the correct picking time, *and carried, not carted,* to the storeroom where they were gently placed on enamel ware plates which were arranged on shelves in the basement closet. If a specimen was bumped, scratched or dented in the handling, it was discarded. Only physically perfect apples were used. This fact may explain in part the extreme tolerance of many varieties although this was only one of many factors that permitted long preservation. The premature deterioration of many fruits has long been recognized as due to careless handling. Some people who fail to recognize this fact doubtless sustain much loss by it as a result of their lack of attention to this detail.

The apples were carefully examined each week in order to observe the rate of deterioration and to remove all decaying specimens. Ordinarily, 10 apples were used to represent each variety on each plate and duplicate plates were provided. The test of any variety was discontinued when 60 percent of the specimens had begun to decay.

The details of the story of varietal tolerance are given in tables VII to XI. These show the date of storing, the end of storage for each variety, the days of tolerance, the total heat units, the average, maximum and minimum temperatures and humidities for each variety for its period. The tabular arrangement proceeds from the least tolerant to the most tolerant varieties. The column headed "total units" is the summary of all the readings at two-hour periods for the time covered by each variety in storage. The average temperatures and humidities were obtained by dividing the number of two-hour counts by the total degrees credited to each variety. The highest and lowest temperature figures are inserted to show the range for each period.

Let us note the records of the three most tolerant varieties of each year.

In 1916-17 Mann kept from October 3 to September 10, a period of 342 days. The total heat units as secured from the two-hour dial readings for Mann amounted to 215,724, minimum, maximum and average temperatures being respectively 33°, 80° and 53° F.

In 1917-18 Baldwin kept from October 6 until August 5, a period of 303 days. The total heat units from the two-hour readings for Baldwin amounted to 181,946, and minimum, maximum and average temperatures were 32°, 78° and 50° F. The humidity records for Baldwin were incomplete, since the instrument was not installed till a week after this variety was stored, but they resembled those for Sutton, its near competitor. The figures are those for relative humidity and represent the percent of saturation.

In 1919-20 Mann outranked its 32 competitors. It was put in storage September 18 and kept until August 9, a period of 326 days. The total heat units for the period amounted to 200,333, minimum, maximum and average temperatures being 30°, 82° and 51° F. The high average here was due to the long summer time of high temperature. The total humidity units for Mann were 258,135, with a minimum of 39°, a maximum of 83°, but an average of 66°. The extremes in percent of moisture were only temporary and were caused by the ventilation of the room.

The endurance of each variety in the experiments can be ascertained by reference to the tables, from which comparisons may be made.

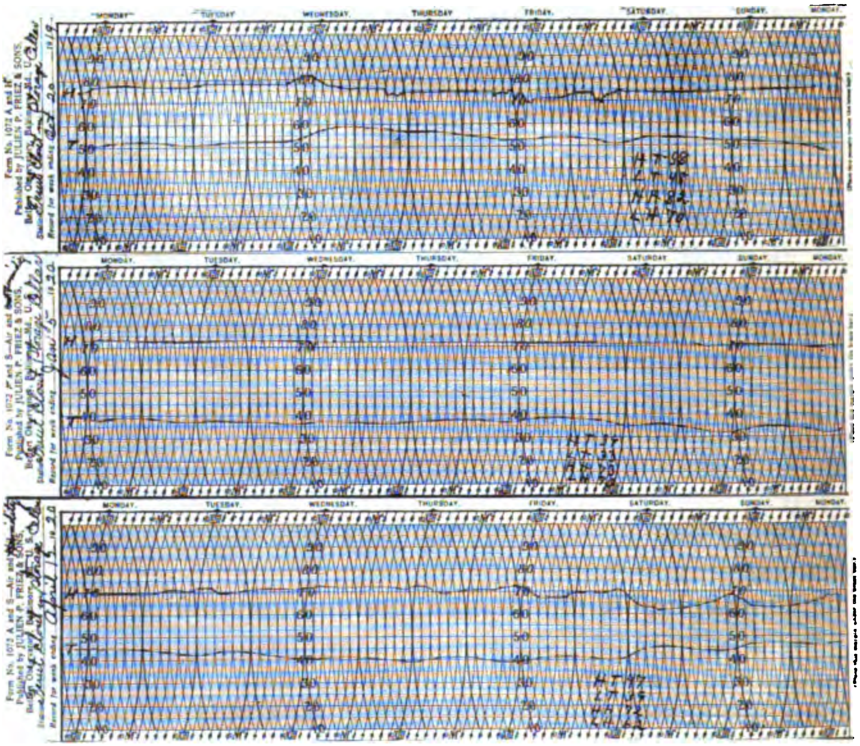


**CHART V**—Seven-day dial sheets from thermograph and hygrograph instruments, showing temperatures and humidity records for the weeks ending Oct. 20, 1919, Jan. 5, 1920, April 19, 1920.

With respect to temperature it is seen that in general the averages are located mostly in the forties. Shiawassee and Hass in 1919-20 were exposed to an average temperature of 42°, Ben Davis and Sutton 51°, and Mann 57°. During this season temperatures ranged from 82° to 30°; the latter prevailing for only a few hours in midwinter, the former during a period in July. The temperature during the winter months was very uniform as the entirely typical photograph of a week of considerable extremes of winter temperature would indicate.

The humidity data on the dials show many fluctuations of short duration, most of which were due to the necessary ventilation of the fruit room. The greatest humidity of the 1917-18 season which occurred in February was 96°; in 1919-20 it was 83° and occurred in November. The lowest humidity which occurred in April, 1917-18 was 67°, and in 1919-20, the lowest was 39° which occurred in May. The average humidity data for different varieties necessarily are unlike, inasmuch as there were differences either in the date for the beginning or the ending of the period for each variety.

The variations from month to month for the season of 1919-20 are shown in table VI. The records are quite typical of those of other years.

TABLE VI—VARIATIONS OF TEMPERATURE AND HUMIDITY
STORAGE SEASON 1919-1920

| Month | Temperature | | Humidity | |
|---|---|---|---|---|
| | Low | High | Low | High |
| **August** | 62 | 76 | 65 | 77 |
| **September** | 65 | 72 | 64 | 82 |
| **October** | 47 | 75 | 64 | 82 |
| **November** | 32 | 51 | 70 | 83 |
| **December** | 30 | 45 | 70 | 81 |
| **January** | 30 | 39 | 58 | 73 |
| **February** | 30 | 41 | 58 | 73 |
| **March** | 35 | 57 | 59 | 77 |
| **April** | 39 | 58 | 60 | 71 |
| **May** | 45 | 78 | 39 | 80 |
| **June** | 62 | 78 | 45 | 78 |
| **July** | 70 | 82 | 47 | 52 |
| **August** | 71 | 80 | 40 | 50 |

TABLE VII—VARIETY TOLERANCE IN STORAGE, 1916-17

| Variety | Stored | Removed | Duration, days | Temperature | | | |
|---|---|---|---|---|---|---|---|
| | | | | Total units | Average | Highest | Lowest |
| Red Astrachan | Aug. 24 | Sept. 28 | 35 | 27,180 | 65 | 76 | 54 |
| Longfield | Sept. 15 | Feb. 2 | 130 | 70,650 | 45 | 72 | 33 |
| McMahon | Sept. 29 | Feb. 28 | 152 | 80,215 | 44 | 70 | 33 |
| Gravenstein | Sept. 29 | Mar. 1 | 153 | 80,780 | 44 | 70 | 33 |
| St. Lawrence | Sept. 20 | Feb. 20 | 153 | 82,987 | 45 | 72 | 33 |
| Haas | Sept. 20 | Mar. 26 | 187 | 101,802 | 45 | 72 | 33 |
| Spitzenburg | Oct. 17 | May 16 | 211 | 119,270 | 47 | 62 | 33 |
| McIntosh | Oct. 2 | May 10 | 220 | 120,547 | 46 | 67 | 33 |
| Twenty Ounce | Sept. 29 | May 16 | 229 | 126,626 | 46 | 70 | 33 |
| N. W. Greening | Oct. 12 | June 1 | 232 | 127,627 | 46 | 62 | 33 |
| Patten Greening | Sept. 29 | May 22 | 235 | 130,569 | 47 | 70 | 33 |
| Y. Bellflower | Oct. 11 | June 7 | 239 | 132,509 | 46– | 62 | 33 |
| Wealthy | Sept. 20 | May 16 | 238 | 133,657 | 47 | 72 | 33 |
| Fallawater | Oct. 17 | June 7 | 233 | 133,856 | 48 | 62 | 33 |
| Sutton | Oct. 12 | June 10 | 241 | 133,993 | 46 | 62 | 33 |
| Shiawassee | Oct. 2 | June 1 | 242 | 134,900 | 46 | 67 | 33 |
| Baldwin | Oct. 12 | June 11 | 242 | 135,419 | 47 | 62 | 33 |
| Fameuse | Sept. 29 | May 30 | 243 | 135,672 | 47 | 70 | 33 |
| Golden Russet | Oct. 4 | June 7 | 246 | 138,326 | 47 | 67 | 33 |
| R. I. Greening | Oct. 2 | June 10 | 251 | 141,266 | 47 | 67 | 33 |
| Hubbardston | Oct. 12 | June 20 | 251 | 142,024 | 47 | 65 | 33 |
| Pumpkin Sweet | Sept. 28 | June 7 | 252 | 142,053 | 47 | 72 | 33 |
| Northern Spy | Oct. 11 | June 20 | 252 | 142,700 | 47 | 65 | 33 |
| Pewaukee | Sept. 28 | June 11 | 256 | 145,639 | 47 | 72 | 33 |
| Bismarck | Oct. 12 | June 27 | 258 | 147,447 | 48 | 65 | 33 |
| Tolman | Oct. 1 | June 20 | 262 | 149,968 | 48 | 67 | 33 |
| Wolf River | Sept. 28 | June 20 | 265 | 152,244 | 48 | 72 | 33 |
| Boiken | Oct. 12 | July 9 | 270 | 156,855 | 48 | 70 | 33 |
| Scott | Oct. 12 | July 17 | 278 | 163,277 | 48 | 71 | 33 |
| Jonathan | Oct. 2 | July 17 | 288 | 170,550 | 49 | 67 | 33 |
| King | Sept. 28 | July 17 | 292 | 173,497 | 50 | 72 | 33 |
| Westfield | Sept. 28 | Aug. 10 | 318 | 195,841 | 51 | 80 | 33 |
| Ben Davis | Oct. 17 | Sept. 4 | 322 | 206,605 | 53 | 80 | 33 |
| Mann | Oct. 3 | Sept. 10 | 342 | 215,724 | 53 | 80 | 33 |

### TABLE VIII—VARIETY TOLERANCE IN STORAGE, 1917-18

| Variety | Stored | Removed | Duration, days | Temperature |  |  |  | Humidity |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Total units | Average | Highest | Lowest | Total units | Average | Highest | Lowest |
| Red Astrachan | Aug. 24 | Oct. 3 | 40 | 30,381 | 63 | 74 | 50 | ...... | .. | .. | .. |
| Longfield | Oct. 13 | Mar. 15 | 153 | 78,117 | 43 | 61 | 32 | 160,031 | 87 | 96 | 76 |
| Roman Stem | Oct. 13 | Mar. 15 | 153 | 78,117 | 43 | 61 | 32 | 160,031 | 87 | 96 | 76 |
| St. Lawrence | Oct. 3 | Mar. 15 | 163 | 84,809 | 43 | 60 | 32 | ...... | .. | .. | .. |
| Fameuse | Nov. 15 | May 13 | 179 | 90,949 | 47 | 62 | 32 | 181,631 | 85 | 96 | 67 |
| Twenty Ounce | Oct. 13 | Apr. 10 | 179 | 92,074 | 43 | 61 | 32 | 185,986 | 87 | 96 | 70 |
| McIntosh | Nov. 15 | May 22 | 188 | 97,568 | 43 | 65 | 32 | 190,888 | 85 | 96 | 67 |
| Tolman | Nov. 15 | May 22 | 188 | 97,568 | 43 | 65 | 32 | 190,888 | 85 | 96 | 67 |
| Scott | Oct. 13 | May 20 | 219 | 116,911 | 45 | 65 | 32 | 223,763 | 85 | 96 | 67 |
| Wealthy | Oct. 6 | May 15 | 221 | 118,484 | 45 | 62 | 32 | ...... | .. | .. | .. |
| R. I. Greening | Nov. 15 | June 20 | 217 | 119,236 | 46 | 64 | 32 | 222,393 | 85 | 96 | 67 |
| Shiawassee | Oct. 13 | June 1 | 231 | 125,916 | 45 | 64 | 32 | 236,681 | 85 | 96 | 67 |
| Pumpkin Sweet | Oct. 13 | June 1 | 231 | 125,916 | 45 | 64 | 32 | 236,681 | 85 | 96 | 67 |
| Jonathan | Nov. 16 | July 1 | 227 | 126,795 | 47 | 70 | 32 | 230,005 | 84 | 96 | 67 |
| Arctic | Nov. 15 | July 1 | 228 | 127,275 | 47 | 70 | 32 | 234,095 | 86 | 96 | 67 |
| Y. Bellflower | Oct. 13 | June 5 | 235 | 129,046 | 46 | 78 | 32 | 241,019 | 86 | 96 | 67 |
| Ben Davis | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| Bismarck | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| Fallawater | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| Haas | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| Hubbardston | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| King | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| N. W. Greening | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| Spitzenburg | Oct. 13 | June 20 | 250 | 140,132 | 47 | 64 | 32 | 257,380 | 86 | 96 | 67 |
| Pewaukee | Oct. 6 | June 20 | 257 | 144,837 | 47 | 68 | 32 | ...... | .. | .. | .. |
| Golden Russet | Oct. 13 | July 1 | 261 | 148,261 | 47 | 70 | 32 | 269,082 | 86 | 96 | 67 |
| Boiken | Oct. 13 | July 28 | 288 | 170,531 | 49 | 72 | 32 | 297,500 | 86 | 96 | 67 |
| Northern Spy | Oct. 13 | July 28 | 288 | 170,531 | 49 | 72 | 32 | 297,500 | 86 | 96 | 67 |
| Wolf River | Oct. 6 | July 28 | 295 | 175,239 | 50 | 77 | 32 | ...... | .. | .. | .. |
| Mann | Oct. 13 | Aug. 5 | 296 | 177,238 | 50 | 78 | 32 | 305,471 | 86 | 96 | 67 |
| Westfield | Oct. 13 | Aug. 5 | 296 | 177,238 | 50 | 78 | 32 | 305,471 | 86 | 96 | 67 |
| Sutton | Oct. 13 | Aug. 5 | 296 | 177,238 | 50 | 78 | 32 | 305,471 | 86 | 96 | 67 |
| Baldwin | Oct. 6 | Aug. 5 | 303 | 181,946 | 50 | 78 | 32 | ...... | .. | .. | .. |

TABLE IX—VARIETY TOLERANCE IN STORAGE, 1919-20

| Variety | Stored | Removed | Duration, days | Temperature | | | | Humidity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total units | Average | Highest | Lowest | Total units | Average | Highest | Lowest |
| Twenty Ounce | Sept. 15 | Feb. 9 | 144 | 73,895 | 43 | 75 | 30 | 127,126 | 74 | 83 | 58 |
| Oldenburg | July 29 | Nov. 19 | 113 | 78,320 | 58 | 76 | 37 | 101,111 | 75 | 83 | 64 |
| Haas | Sept. 18 | Mar. 17 | 181 | 91,244 | 42 | 75 | 30 | 158,872 | 73 | 83 | 58 |
| Pumpkin Sweet | Sept. 17 | Mar. 17 | 182 | 91,763 | 42 | 75 | 30 | 159,768 | 73 | 83 | 58 |
| Patten | Sept. 17 | Apr. 1 | 197 | 100,274 | 42 | 75 | 30 | 171,636 | 73 | 83 | 58 |
| Shiawassee | Sept. 18 | Apr. 2 | 197 | 100,323 | 42 | 75 | 30 | 171,528 | 73 | 83 | 58 |
| Wealthy | Sept. 16 | Apr. 1 | 198 | 100,987 | 42 | 75 | 30 | 172,332 | 73 | 83 | 58 |
| Longfield | Sept. 5 | Apr. 1 | 209 | 108,650 | 43 | 75 | 30 | 181,558 | 72 | 83 | 58 |
| McMahon | Sept. 5 | Apr. 2 | 210 | 109,218 | 43 | 75 | 30 | 182,346 | 72 | 83 | 58 |
| Cooper | Sept. 16 | May 1 | 228 | 118,311 | 43 | 75 | 30 | 195,575 | 71 | 83 | 58 |
| St. Lawrence | Sept. 16 | May 1 | 228 | 118,311 | 43 | 75 | 30 | 195,575 | 71 | 83 | 58 |
| Northern Spy | Sept. 19 | May 15 | 239 | 125,401 | 44 | 75 | 30 | 201,633 | 70 | 83 | 39 |
| Bismarck | Sept. 18 | May 15 | 240 | 126,160 | 44 | 75 | 30 | 202,491 | 70 | 83 | 39 |
| Arctic | Sept. 18 | May 19 | 244 | 129,044 | 44 | 75 | 30 | 205,483 | 70 | 83 | 39 |
| Fameuse | Sept. 18 | May 31 | 256 | 138,261 | 45 | 78 | 30 | 215,428 | 70 | 83 | 39 |
| Golden Russet | Sept. 18 | May 31 | 256 | 138,261 | 45 | 78 | 30 | 215,428 | 70 | 83 | 39 |
| R. I. Greening | Sept. 19 | June 1 | 256 | 138,490 | 45 | 78 | 30 | 215,563 | 70 | 83 | 39 |
| McIntosh | Sept. 18 | June 7 | 263 | 144,104 | 46 | 78 | 30 | 221,381 | 70 | 83 | 39 |
| Wolf River | Sept. 18 | June 7 | 263 | 144,104 | 46 | 78 | 30 | 221,381 | 70 | 83 | 39 |
| King | Sept. 19 | June 9 | 274 | 153,602 | 47 | 75 | 30 | 227,612 | 69 | 83 | 39 |
| Boiken | Sept. 18 | June 19 | 275 | 154,361 | 48 | 78 | 30 | 228,470 | 71 | 83 | 39 |
| Pewaukee | Sept. 18 | June 19 | 275 | 154,361 | 48 | 78 | 30 | 228,470 | 71 | 83 | 39 |
| Westfield | Sept. 18 | June 19 | 275 | 154,361 | 48 | 78 | 30 | 228,470 | 71 | 83 | 39 |
| Scott | Sept. 19 | June 29 | 284 | 162,104 | 48 | 78 | 30 | 233,333 | 68 | 83 | 39 |
| Spitzenburg | Sept. 20 | July 14 | 298 | 174,783 | 49– | 80 | 30 | 241,294 | 67 | 83 | 39 |
| Y. Bellflower | Sept. 19 | July 14 | 299 | 175,643 | 49 | 80 | 30 | 242,364 | 68 | 83 | 39 |
| Baldwin | Sept. 19 | July 14 | 299 | 175,643 | 49 | 80 | 30 | 242,364 | 68 | 83 | 39 |
| Tolman | Sept. 18 | July 14 | 300 | 176,402 | 49 | 80 | 30 | 243,222 | 68 | 83 | 39 |
| Rome | Sept. 18 | July 14 | 300 | 176,402 | 49 | 80 | 30 | 243,222 | 68 | 83 | 39 |
| Fallawater | Sept. 19 | July 19 | 304 | 180,422 | 49 | 82 | 30 | 245,215 | 67 | 83 | 39 |
| Ben Davis | Sept. 18 | Aug. 2 | 319 | 193,835 | 51 | 82 | 30 | 254,156 | 66 | 83 | 39 |
| Sutton | Sept. 18 | Aug. 2 | 319 | 193,835 | 51 | 82 | 30 | 254,156 | 66 | 83 | 39 |
| Mann | Sept. 18 | Aug. 9 | 326 | 200,333 | 51 | 82 | 30 | 258,135 | 66 | 83 | 39 |

### TABLE X—NUMBER OF DAYS IN STORAGE

WITH THREE-YEAR AVERAGE

| Variety | 1916-17 | 1917-18 | 1919-20 | Total | Average |
|---|---|---|---|---|---|
| Red Astrachan | 35 | 40 | ... | 75 | 38 |
| Longfield | 130 | 153 | 209 | 492 | 164 |
| St. Lawrence | 153 | 163 | 228 | 544 | 181 |
| Twenty Ounce | 229 | 179 | 144 | 552 | 184 |
| Haas | 187 | 250 | 181 | 618 | 206 |
| Wealthy | 238 | 221 | 198 | 657 | 219 |
| Pumpkin Sweet | 252 | 231 | 182 | 665 | 222 |
| Shiawassee | 242 | 231 | 197 | 760 | 223 |
| McIntosh | 220 | 188 | 263 | 671 | 224 |
| Fameuse | 243 | 179 | 256 | 678 | 226 |
| Arctic | ... | 228 | 244 | 472 | 236 |
| N. W. Greening | 232 | 250 | ... | 482 | 241 |
| R. I. Greening | 251 | 217 | 256 | 724 | 241 |
| Bismarck | 258 | 250 | 240 | 748 | 249 |
| Tolman | 262 | 188 | 300 | 750 | 250 |
| Golden Russet | 246 | 261 | 256 | 753 | 251 |
| Hubbardston | 251 | 250 | ... | 501 | 251 |
| Spitzenburg | 211 | 250 | 298 | 759 | 253 |
| Jonathan | 288 | 227 | ... | 515 | 258 |
| Y. Bellflower | 239 | 235 | 299 | 773 | 258 |
| Northern Spy | 252 | 288 | 239 | 779 | 260 |
| Scott | 278 | 219 | 284 | 781 | 260 |
| Fallawater | 233 | 250 | 304 | 787 | 262 |
| Pewaukee | 256 | 257 | 275 | 788 | 263 |
| King | 292 | 250 | 274 | 816 | 272 |
| Wolf River | 265 | 295 | 263 | 823 | 274 |
| Baldwin | 242 | 303 | 299 | 844 | 281 |
| Sutton | 241 | 296 | 319 | 856 | 285 |
| Boiken | 270 | 288 | 275 | 883 | 294 |
| Westfield | 318 | 296 | 275 | 889 | 296 |
| Ben Davis | 322 | 250 | 319 | 891 | 297 |
| Mann | 342 | 296 | 326 | 964 | 321 |

## PROGRESS OF DECAY

The subjoined tables show the relative endurance of many varieties up to the time of decay of the first specimen in the variety lot. With the original weight given, and the weight of the lot at the time of removal of the first decayed specimen, it has been possible to compute the loss of weight in grams and the percentage of loss up to the time noted. It is important to note how small the shrinkages were, for this attests to the favorable condition of storage. Since it was decided that when 60 percent of the apples in any variety lot showed conspicuous decay, the arrival of that condition of affairs marked the end for that variety. It is seen how long was the interim between the inauguration of the storage period and the first decay and, likewise, between the first decay and the 60 percent decay for any variety.

Haas showed the first symptoms of decay in 33 days, St. Lawrence in 35, Baldwin in 94, R. I. Greening in 135, Fameuse in 144, McIntosh in 181, Wealthy in 183, Northern Spy in 225 and Ben Davis in 275 days. With respect to the interim from the first signs of decay and its extent to 60 percent, the period ranged from 12 days for Boiken to 205 days for Baldwin. Obviously the first appearance of decay may or may not be significant, depending upon the variety under consideration. With Pewaukee and Boiken, for instance, the first sign of rot is to be considered as a warning that the end is near; but with Baldwins and Greenings one need not get alarmed at a few decay spots, since these varieties may be slow in passing on to a condition of general decay. One should know the relative endurance of varieties in storage and act in accordance with that knowledge.

TABLE XI—DECAY IN STORAGE, 1919-20

| Variety | Date stored | Number of apples | Weight of apples in grams | | | Percent loss | Days to first decay | Days from first to 60% decay | Total number of days |
|---|---|---|---|---|---|---|---|---|---|
| | | | Original | At first removal | Loss | | | | |
| Oldenburg | July 29 | 5 | 384 | 285 | 99 | 26 | 57 | 56 | 113 |
| Longfield | Sept. 5 | 4 | 207 | 190 | 17 | 8 | 157 | 52 | 209 |
| McMahon | Sept. 5 | 5 | 547 | 495 | 52 | 10 | 194 | 16 | 210 |
| Cooper | Sept. 16 | 2 | 253 | 247 | 6 | 2 | 95 | 113 | 228 |
| Wealthy | Sept. 16 | 5 | 434 | 400 | 34 | 8 | 183 | 15 | 198 |
| St. Lawrence | Sept. 16 | 3 | 266 | 257 | 9 | 3 | 35 | 193 | 228 |
| Patten | Sept. 17 | 5 | 645 | 616 | 29 | 4 | 84 | 113 | 197 |
| Pumpkin Sweet | Sept. 17 | 14 | 855 | 821 | 34 | 4 | 84 | 98 | 182 |
| Ben Davis | Sept. 18 | 10 | 640 | 580 | 60 | 9 | 275 | 44 | 319 |
| Boiken | Sept. 18 | 5 | 584 | 480 | 104 | 18 | 263 | 12 | 275 |
| Bismarck | Sept. 18 | 5 | 485 | 443 | 42 | 9 | 226 | 14 | 240 |
| Fameuse | Sept. 18 | 10 | 800 | 770 | 30 | 4 | 144 | 112 | 256 |
| Golden Russet | Sept. 18 | 10 | 945 | 890 | 55 | 6 | 197 | 59 | 256 |
| Haas | Sept. 18 | 5 | 368 | 351 | 17 | 5 | 33 | 148 | 181 |
| McIntosh | Sept. 18 | 10 | 1,191 | 1,080 | 111 | 9 | 181 | 82 | 263 |
| Pewaukee | Sept. 18 | 5 | 618 | 540 | 78 | 13 | 263 | 12 | 275 |
| Rome | Sept. 18 | 4 | 364 | 310 | 54 | 15 | 257 | 43 | 300 |
| Shiawassee | Sept. 18 | 5 | 669 | 650 | 19 | 3 | 93 | 104 | 197 |
| Sutton | Sept. 18 | 10 | 967 | 924 | 43 | 4 | 144 | 175 | 319 |
| Tolman | Sept. 18 | 5 | 492 | 433 | 59 | 12 | 144 | 156 | 300 |
| Westfield | Sept. 18 | 5 | 479 | 420 | 59 | 12 | 226 | 49 | 275 |
| Wolf River | Sept. 18 | 5 | 772 | 715 | 57 | 8 | 226 | 37 | 263 |
| Baldwin | Sept. 19 | 10 | 1,205 | 1,161 | 44 | 4 | 94 | 205 | 299 |
| Bellflower | Sept. 19 | 10 | 1,306 | 1,180 | 126 | 10 | 262 | 37 | 299 |
| Fallawater | Sept. 19 | 5 | 1,292 | 1,060 | 232 | 18 | 262 | 42 | 304 |
| King | Sept. 19 | 5 | 935 | 902 | 33 | 4 | 73 | 201 | 274 |
| Northern Spy | Sept. 19 | 10 | 1,255 | 1,140 | 115 | 9 | 225 | 14 | 239 |
| R. I. Greening | Sept. 19 | 10 | 995 | 930 | 65 | 7 | 135 | 121 | 256 |
| Scott | Sept. 19 | 10 | 667 | 590 | 77 | 12 | 225 | 59 | 284 |
| Spitzenburg | Sept. 20 | 10 | 901 | 730 | 171 | 19 | 224 | 74 | 298 |

Earlier trials made by several investigators have shown how necessary low temperatures and high humidities are in the successful storage of apples. The extent to which it was possible to conform to these requirements in these experiments is shown in the tabulated material published herewith. The averages only can be accepted as reliable indices for storage endurance.

The same variety of apple will show some differences in storage capabilities in different seasons. Warehouse men recognize this fact and sometimes lose heavily through the premature decay of a given variety. Farmers who store apples in the home cellar may have similar, though less serious, experiences. The differences must be attributed in part to seasonal vagaries as well as in part to the conditions of storage. The climate during one season is often not duplicated in its successor. Some conditions are quite uncontrollable. For example, Baldwin in 1916-17 kept only 242 days, but in 1917-18 303 days and in 1919-20 299 days, the average duration being 281 days. St. Lawrence, a fall apple, showed about the same endurance during two of the three years, 153, 163, 228 days, an average of 181. Mann, which was an extremely good keeper, remained in good condition during the three seasons for 342, 296 and 325 days, a three-year average of 321 days. The assembled figures on the subjoined tables show the number of days each variety kept each year and the average tolerance for the three years.

The variety orchard is a thing of the past for commercial purposes; not, however, for the home supply. A diversified supply of apples is highly desirable on the farm, unless one can provide suitable storage for a few sorts for a long time. Furthermore, many people have a definite preference for certain varieties. One person prefers McIntosh or Northern Spy, and another Greening or Baldwin.

These trials show that certain varieties exhibit great endurance when proper care is used in their harvest and that, given suitable temperature and humidity conditions, their long preservation is entirely feasible. It is possible to preserve these varieties from 8 to 10 months in the year by following the methods of careful handling, low temperatures and high humidities, such as were employed in these experiments; or by the use of the bordeaux-sawdust pack described in Vermont Station Bulletin 186, entitled, "Farm Apple Storage."

# APPLE CION SELECTION FROM HIGH AND LOW YIELDING PARENT TREES

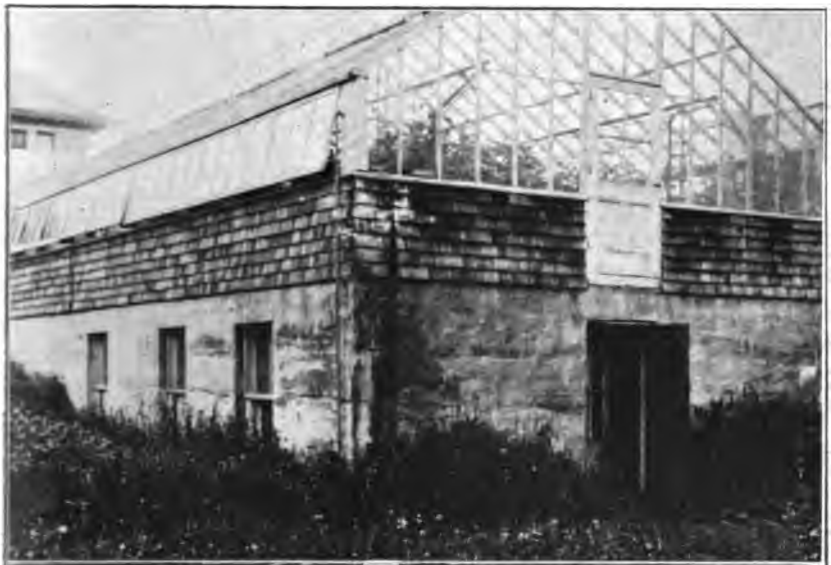
## PRELIMINARY REPORT

In 1910 an experiment was started for the purpose of testing the relative merits of cions derived from high and low yielding apple trees. At the inception of the trial the question was raised as to whether the yielding propensities of either heavy or light bearing trees could be projected to other trees through the process of cion selection and graftage. In order to answer the question it became necessary to secure the information through experimentation. Consequently, cions were secured from mature trees whose croppage powers for long terms of years were intimately known.

The varieties used were Northern Spy, Wealthy, Rhode Island Greening, Patten, Red Astrachan, McMahon and Pumpkin Sweet and their cions were grafted into trees in the station orchard where their performance could be observed.

The Northern Spy cions were secured in the orchard of T. B. Landon at South Hero, where there were two trees of contrasting bearing habits. One of the trees had borne well for a number of years and its fruit was beautiful and of superior quality. Specimens from this tree won a blue ribbon prize at one of the New England fruit shows. A little distance from this tree was another tree which was decidedly dissimilar in respect both to the quality and the quantity of its fruitage. The orchardist stated that the latter tree was worthless, that it had never produced more than a peck of apples in any one year, and that even this small quantity was of poor quality. The tree was over 50 years old and grew in good soil. The two parent trees were, therefore, in sharp contrast as to their crop producing powers. The cions were grafted into Rome and Oldenburg trees.

The Wealthy cions were secured in part from Luther Putnam of Cambridge, in whose orchard grew two trees of the same age and in the same row but with contrasting yield records. Conditions of culture and environment, as far as known and observable, were alike in every particular, and yet one tree regularly produced from three to four times as many apples, both by count and by volume, as did the other. Another set of cions was furnished by Prof. W. T. McCoun of the Central Experimental Farms at Ottawa, Canada. The contributor stated that the trees from which they were taken were very unlike in bearing habits, one being high, the other low. The Wealthy cions were



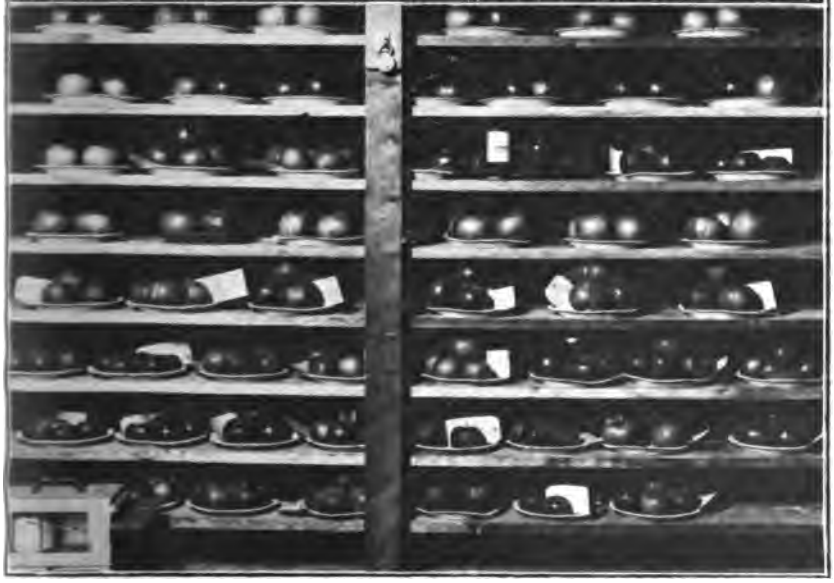


PLATE III—Concrete basement room used for storage purposes. Note the double doors and inter-door space between them; also surface of ground windows for ventilation and regulation of temperature.

Storage closet with shelves for plates of apples in basement room. Note hygrograph, below at left, for recording moisture content of the air and thermograph, near center at right, for recording the temperature of the room.

**Plate** IV—15-year old orchard; time to remove filler trees.

**Plate** V—Trees from which productive and unproductive cions were taken.

grafted into Arctic, Tetofsky, Mann, Yellow Bellflower, Yellow Transparent and Baldwin trees.

The Pound Sweet cions were secured from different places. Some were secured from W. C. Holcomb of Isle La Motte, from a 15-year old tree which gave good crops of high quality apples, while others from an unproductive tree were secured of C. O. Ormsbee of Montpelier. These cions were grafted into Hubbardston, Tolman and Boiken.

The Rhode Island Greening cions came from trees in the orchard of Arthur Hill at Isle La Motte, where were two trees of different crop records, one high, and one low, and were grafted into Arctic, Tolman and Ben Davis.

The Patten and McMahon cions were secured from the Central Experimental Farms at Ottawa, Canada. The yield records in both cases were in marked contrast. The cions of Patten were grafted into McIntosh, Tetofsky and Alexander, and those of McMahon into Arctic trees.

The Red Astrachan cions were secured from H. C. Sanborn and H. P. Cummings of Thetford; the former furnishing the unproductive, the latter the productive ones. The trees from which the cions were taken were known to have been fairly constant in their fruiting habits for some years. These cions were set into Arctic trees.

Two hundred and forty-eight cions were used in the test. Many more than this number were set, but some died and a few were discarded as unsuitable. Forty-six trees were grafted with 120 cions from productive trees and 128 from unproductive ones. At the close of the 10 year period (1920), 169 of these 248 cions had borne, 86 of them from productive and 83 from unproductive trees.

The following table gives the data for the selected cions of the different varieties and shows the yield records of both the productive and the unproductive. The Northern Spy cions have not as yet borne fruit, this variety being a tardy bearer.

After the grafted twigs had become established a number of cions of each grade were paired, and the performance of each pair was kept separate and recorded for later use. The subjoined table shows the number of cions of each variety, indicated as productive and unproductive, the number of fruits produced, and the weight of the fruits.

TABLE XII—YIELDS OF CIONS DERIVED FROM UNPRODUCTIVE AND FROM PRODUCTIVE TREES

| Variety | Unproductive | | | Productive | | | Gain or loss for productive | |
|---|---|---|---|---|---|---|---|---|
| | Number of cions | Average number of fruits | Average weight of fruits | Number of cions | Average number of fruits | Average weight of fruits | Number of fruits | Weight of fruits |
| | | | pounds | | | pounds | % | % |
| Pumpkin Sweet | 35 | 16 | 4.7 | 23 | 34 | 10.9 | 113 | 132 |
| Red Astrachan | 4 | 128 | 16.3 | 7 | 134 | 21.0 | 5 | 29 |
| Wealthy | 26 | 140 | 29.9 | 23 | 138 | 33.7 | —1 | 13 |
| R. I. Greening | 9 | 19 | 3.1 | 17 | 17 | 5.1 | —11 | 65 |
| McMahon | 19 | 72 | 17.7 | 18 | 23 | 4.9 | —68 | —72 |
| Patten | 11 | 425 | 117.2 | 7 | 102 | 28.2 | —76 | —76 |
| Northern Spy | (24) | ... | .... | (25) | ... | ... | ... | ... |
| Total | 104 | 800 | 188.9 | 95 | 448 | 84.9 | ... | ... |
| Average | ... | 133 | 31.5 | .. | 75 | 14.2 | —44 | —55 |

The cions derived from productive trees have done no better as the whole, in fact up to date they have done scarcely as well, as those secured from unproductive trees. The outcome favored the productive cions in the case of two varieties, Pumpkin Sweet and Red Astrachan; the unproductive cions in the case of two varieties, McMahon and Patten; was indeterminate in respect to two, Rhode Island Greening and Wealthy; and no results were secured from the Northern Spy, as they had not borne at all. In view of the fact that in many cases these cions of supposedly different values were grafted into the same variety, often into the same individual trees, eventually a definite and a reliable answer to the query as to their relative values should be secured even though it is long delayed.

This report on cion selection is merely a preliminary statement. Another ten years must doubtless elapse before sufficient data are accumulated to warrant one in drawing valid conclusions as to the basic question involved in this experiment. However, it is safe to say that the results thus far secured, because of their inconsistency, do not justify deduction except that they clearly do not afford affirmative support to the cion selection idea.

JULY, 1921 BULLETIN 222

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# YIELD AND QUALITY IN HUBBARD SQUASH

By M. B. CUMMINGS and W. C. STONE

BURLINGTON
Free Press Printing Company
1921

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# BULLETIN 222: YIELD AND QUALITY IN HUBBARD SQUASH

By M. B. Cummings and W. C. Stone[1]

## SUMMARY

Seed selection experiments were conducted with the Hubbard squash to ascertain the possibility of modifying the yield and controlling the quality; statistical studies of variations were made to show the relative influence of different methods of pollination and seed selection; and data were compiled to show the influence of seed selection with open-pollinated plants for a period of six years, 1911 to 1916; and with self-pollinated and inter-crossed plants for four years, 1914 to 1917.

The immediate effect of self-pollination was found to be negligible. Inter-crossing was without apparent effect on yield. In both cases the progeny, which were the products of selections from high- and low-yielding strains, were segregated and maintained with good contrasts as to yields, entirely independent of the method of pollination. Neither self-pollination nor inter-crossing were influential in controlling yield; but seed selection was effective.

Seed selections from open-pollinated plants of high and low producing strains were made for the six-year period, 1911 to 1916. After the first year the "highs" were superior to the "lows" in yields, ranging from 26 to 102 percent, the maximum being reached in the fourth year. The method of pollination was ineffective, seed selection being the controlling factor.

Trials made by three farmers, who used seed supplied by the Station afforded results comparable to those obtained on the station grounds. "Highs" exceeded "lows" in the several instances by percentages ranging from 72 to 169.

Statistical studies were made during several years with reference to variations in weight per vine and weight per squash under the different treatments, and presentments are made in tabular form for the mean, standard and average deviations and coefficient of variability. The average or mean for the "high" increased from year to year until 1916, showing that new values kept coming in,

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[1] The authors are indebted to A. Parks, station gardener, for assistance in the culture and testing of squash; to J. B. Norton and E. W. Jenkins, former and present assistant horticulturists, for assistance in the computations; and to C. H. Jones, station chemist, for chemical analyses.

thus establishing new starting points in selection. The variations as shown by the coefficient were increased rather than decreased, again showing the nugatory effects of pollination. Among the "lows" there was not much change until 1916, when there was some increase. Variability studies with regard to the weight of the individual squashes were made during five years. The data show the effect of seed selection to have been that of increasing the weights of the "highs" up to certain limits, except among the self-pollinated plants where the "lows" were found to be heavier. The individual fruits of the high yielders were larger.

Correlation computations were made as to the interrelations of the number of leaves and the weight of fruits per vine. Positive results were secured. In 1914, the correlation was .742; in 1915, .610; in 1916, .793; in 1917, .718.

The prolific production of pollen suggests much waste of the energies of the plant, as does, also, the large number of late set squashes which do not mature; and yet such trials of disbudding and pruning as were made proved of no avail in conserving the energies of the plant or in increasing the yield of ripe squashes.

Hubbards vary much in quality. Some are wet, lumpy, stringy and insipid, while others are dry, mealy, sweet and delectable; and there are all gradations between these extremes, and many different combinations of quality factors. Such characters are associated in part with season, soil and maturity, and in part with the breed and its purity of quality. Quality is a generic word and embraces several different things, such as flavor, texture, fibrination and amount of moisture. It is partly a matter of physical characteristics and partly a matter of proportional chemical composition.

Culinary tests were made during four seasons based upon granulation, fibrination, moisture, flavor and general quality. Comparative edibility and palatability tests were made of 952 cooked and unseasoned squashes. Samples were taken of strains 31, 773, 531 and 270, which gave two sets of contrasting grades of quality.

Edibility tests, substantiated by chemical analyses, show that specimens of good quality contain more carbohydrates and less water and crude protein than do those of poor quality. Tables are presented which show the general composition of squashes from composite samples, the proportional amount of essential ingredients by quality classification, and by in-bred strains. In general, the physical analyses and edibility tests indicate what the chemical analysis reveals, namely: differences in the amount of water, crude protein and carbohydrates as between different squashes.

Four separate strains—two good, and two poor—were isolated and grown for several years. Meanwhile, edibility tests have shown that it is possible to project either good or poor quality to succeeding generations under conditions of experimental control. Within certain limits, good squash give rise to good quality progeny and poor squash to poor quality progeny.

A large percentage of the offspring resemble the parent in quality. However, once good quality is secured constant care in seed selection and in flower manipulation are necessary in order to avoid cross-pollination and to maintain good quality.

"Excellent" quality is generally associated with full maturity and ripeness, a hard, thick shell and clear color demarcation between flesh and shell. Excellent specimens have a relatively small number of seeds, not more than two-thirds as many as the poor ones. Large size is not necessarily or usually associated with superior quality, but full maturity is imperative.

It seems clear that one may propagate almost at will either a strain of poor quality or a strain of good quality, and that the characteristics of the parent squash and its immediate ancestry in the main determine the grade of the progeny. Most commercial seed stock is protean in nature and quality; but by means of self-fertilization and seed selection good quality can be promptly isolated and a desirable strain established.

## INTRODUCTION

The history of the species of squash is more obscure than that of any garden vegetable of equal importance. American botanists believe that some forms were cultivated by the Indians and found by the earliest settlers on the Island of Nantucket. The name "squash" was adapted from an American Indian word and is applied in an indefinite way to various plants of the genus Cucurbita. The application of the name does not conform to the specific lines of the plant. According to systemists what are called "summer squashes" are mostly varieties of *Cucurbita Pepo* which includes the pumpkin, while the winter varieties are either *Cucurbita Maxima* or *Cucurbita Moschata.* Within the species *Cucurbita Maxima* are found most winter varieties, such as Hubbard, Butman, Delicious, Warted and Golden Hubbard. The summer forms may be classed under three types: crookneck, scallop and pineapple squashes.

The origin of the Hubbard variety is simple and definite. James J. H. Gregory, of Marblehead, Mass., was the first seedsman to put it into the seed trade and upon the market. The variety was brought to his attention by an old washerwoman named Hubbard, after whom he named it. Gregory claimed that it resembled a variety procured from one of the West Indian Islands which had many of the characteristics of the Hubbard, although its shell was uniformly blue in color and its quality somewhat inferior.

The Hubbard mixes freely with other closely allied varieties, as most gardeners know, but many of its own characters are persistent. It possesses the ability partially to free itself and maintain some but not all of its varietal characteristics and good qualities. It has become a favorite among New England people. It has many merits. It possesses a hard, glossy shell which enhances its ability to withstand shipment and long storage. It keeps in fresh condition with little difficulty. It is easily prepared for the table and is excelled by few vegetables in nutritive value. Whether steamed, boiled, or baked, it furnishes an excellent product, makes good soup, rolls and muffins—a fact which few people appreciate—and squash pie forms a well known and delectable dessert. A high grade Hubbard is surpassed in quality only by the Delicious, which itself is the product of a cross between the Faxon and the Hubbard, from the progeny of which selections were made, the best flavored offspring saved, and in time the Delicious developed and established.

Notwithstanding its excellent qualities and general persistence of type the Hubbard has greatly deteriorated under improper culture. It varies greatly in yield per vine or per acre under normal conditions of crop production. In view of its general importance and popularity as one of our best fall and winter vegetables, it seemed desirable to attempt to learn why such things should be; and in that study a number of interesting questions were raised which could be answered only by experimentation.

## PROBLEM DEFINED

The problem involved was to determine to what extent it is possible to control the quality and modify the yield of Hubbard squash. It was proposed:

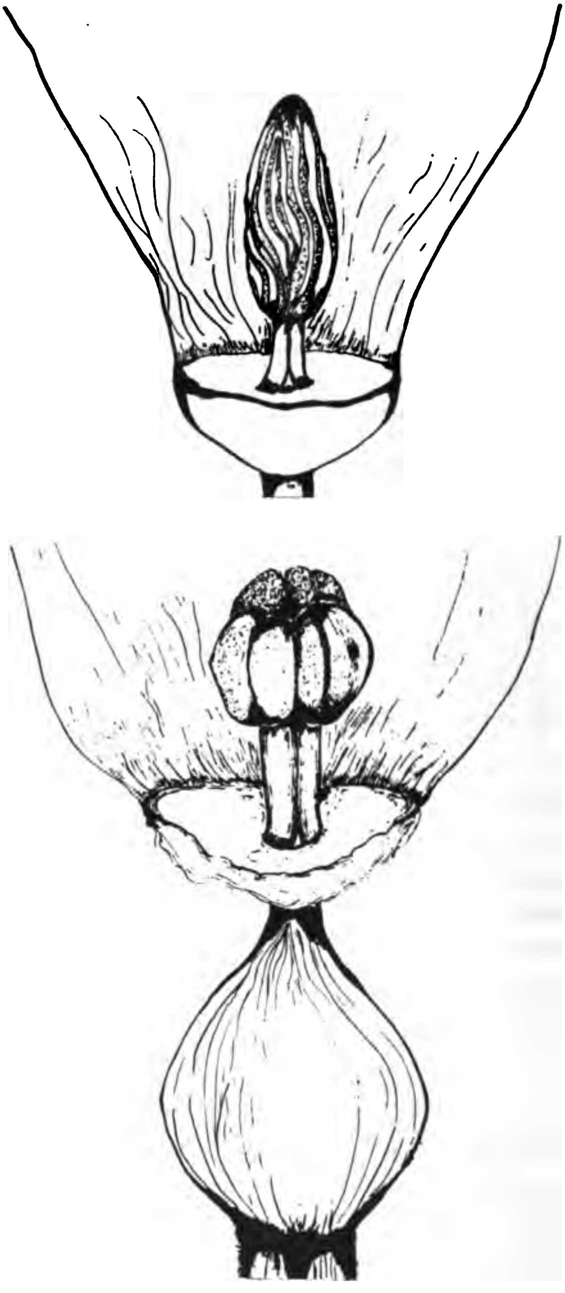
1. To determine the possibility of projecting high- and low-yielding capabilities to the progeny.
2. To ascertain the influence of self-pollination, cross-pollination, and inter-pollination on quality and yield.
3. To conduct pruning and disbudding experiments in order to ascertain their effect on the size of the crop.
4. To ascertain the possible control of quality by making seed selections from good and poor squashes.

## FOUNDATION STOCK

The seed for the foundation was obtained from a crop of squashes that was grown on the University Farm in 1911. From this early crop, selections were made from vines which showed variation in quantity. The experimental area of 1912 was more than three acres in extent, so there was ample opportunity to observe a wide range of variation and to select the extremes in yield.

## POLLINATION WORK

The squash plant is monœcious, the staminate and pistillate blossoms occurring separately on the same vine. The structural differences of the two kinds of flowers are shown in the accompanying drawings. The large corolla which extends beyond the stamens and pistils enables the operator who is dealing with trials involving control of the pollination processes to dispense with pollination bags. The tips of the blossoms may be drawn together and tied with string, thus preventing the intrusions of insects and the access of foreign pollen.



**(a) Vertical view of staminate flowers showing anthers ready to dehisce; (b) Pistillate flowers showing nobs of stigma above, and connected by a slender style with ovary below.**

The pistils thus protected remain unfertilized until the desired time, and the pollen kept pure and uncontaminated. Cotton twine was found suitable for tying the blossoms. When the flowers are ready to be opened for pollination, the string is cut with sharp-pointed scissors. As the pistils and pollen mature, the former are fertilized by carefully removing the string from the corolla enclosing the pistil and placing thereon pure pollen from the desired staminate flower. It is quite possible to re-cover the pistils, and re-tie the corolla after pollination, thus guarding against the access of foreign pollen. This method of flower manipulation is both simple and safe and affords correct results. Indeed, the occasional overlooked and un-pollinated covered blossom which failed to set fruit, furnishes an admirable check and assurance of the reliability of this technical procedure.

Squash blossoms are naturally open-pollinated, through the agency of insects, chiefly bees. Hence the establishment of a pure line of squashes possessing any definite set of characters of necessity involves choice of pollen from definite sources and an artificial method of application.

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EXPLANATION OF TERMS

*Self-fertilization.* That process of fecundation which is accomplished by the direct action of pollen on its own sisterhood of pistils. In the case of squashes, both sexual elements are derived from the same plants, although separate flowers produce those elements. Continuous self-fertilization leads eventually to the development of a "pure line" of descendants, if, at first, the variable progeny are discarded. The term, self-pollinated plants, as used in the following discussion, indicates a plant grown from the seed of a self-pollinated fruit.

*Cross-fertilization.* That process of fecundation effected by pollen from one plant acting upon pistils of another plant. Here the sexual elements are derived from different plants. This process prevents the development of a pure line and insures a more or less mixed progeny. Much cross-pollination naturally occurs. In all probability most untreated squashes are cross-fertilized.

*Open-pollination.* That process of fertilization which occurs at will. With squashes it is generally effected by insects. Open-pollination is the normal, the natural method. The pollen may be derived from the same plant or from the other plants, perhaps as likely from one source as from the other. Open-pollinated plants are therefore of unknown parentage. This method of pollination is common in gardens and fields. The degree of cross-pollination or the amount of self-pollination that occurs among squashes depends upon the source of seed used. If the seed for a crop are all derived from one squash, the result is likely to be that of inter-crossing. If the seed is taken at random from many sources, cross-fertilization is likely to result.

*Inter-crossing.* The process of sexual intermixture of different plants having the same immediate parents. In this case, the offsprings are pure line stock within certain limits. They may be considered as less variable than cross-fertilized progeny and less pure than self-fertilized plants. They are therefore intermediates of the former groups.

The effects of the method of flower treatment as outlined above constitute one phase of investigation presented in this bulletin. The results of different methods of pollination are discussed from data based upon experiments extending over five years.

## INFLUENCE OF SELF-FERTILIZATION ON YIELD

It has been generally accepted as a fact that the continued self-fertilization of a naturally open-pollinated plant is a devitalizing process. The numerous writings of Darwin led to this general conclusion. However, it does not necessarily follow that all plants will respond in the same way and adhere strictly to this rule. Much may depend upon the nature of the plant, its sexual construction and its mode of reproduction. There are some exceptions to most general laws; and in some cases the exceptions are quite numerous.

In the summer of 1914, three sets of plants, representing temporarily at least different yielding propensities, were grown side by side. The sets designated as high and as low yielders were selected from the self-pollinated fruits of plants that showed those tendencies in 1913. By means of self-fertilization, these same sets of plants were continued for the tests in 1915 and 1916. The set comprising the check plants was a composite of high and low production of the preceding year, and were left to be open-pollinated by insects in the usual way.
The comparative yields are shown in the following table:

YIELDS OF SELF-FERTILIZED PLANTS

| Year | Series | Number of plants | Average yield, pounds | Percentage gain or loss over check | |
|---|---|---|---|---|---|
| **1914** | **Check** | **139** | **16.7** | **...** | |
| | **High** | **48** | **22.8** | **+36.5** | |
| | **Low** | **48** | **15.9** | **— 4.8** | |
| **1915** | **Check 1** | **125** | **23.4** | **Check 1** | **Check 2** |
| | **Check 2** | **20** | **21.0** | **...** | **...** |
| | **High** | **44** | **27.6** | **+17.9** | **+31.4** |
| | **Low** | **52** | **21.3** | **— 9.** | **+ 1.4** |
| **1916** | **Check** | **155** | **16.2** | **...** | |
| | **High** | **89** | **21.2** | **+30.9** | |
| | **Low** | **113** | **16.4** | **+ 1.2** | |

The production of self-pollinated, high-yielding plants in 1914 was 37 percent larger than that of the check plants, whereas that from the self-pollinated, low-yielding plants was 5 percent less, the spread being 43 percent. The method of seed selection was more important than the method of fertilization.

In 1915 the self-pollinated high- and low-yielding plants were contrasted with check 1 (the average of high and low from insect-pollinated plants) and with check 2 (grown from mixed seed). In the first instance, the high-yielding and self-fertilized plants outclassed check 1 plants by 18 percent, whereas the low-yielding plants lagged behind the check 1 plants by 9 percent. In the second instance the high-producing plants yielded 31 percent and the low, 1 percent more than the check 2 vines.

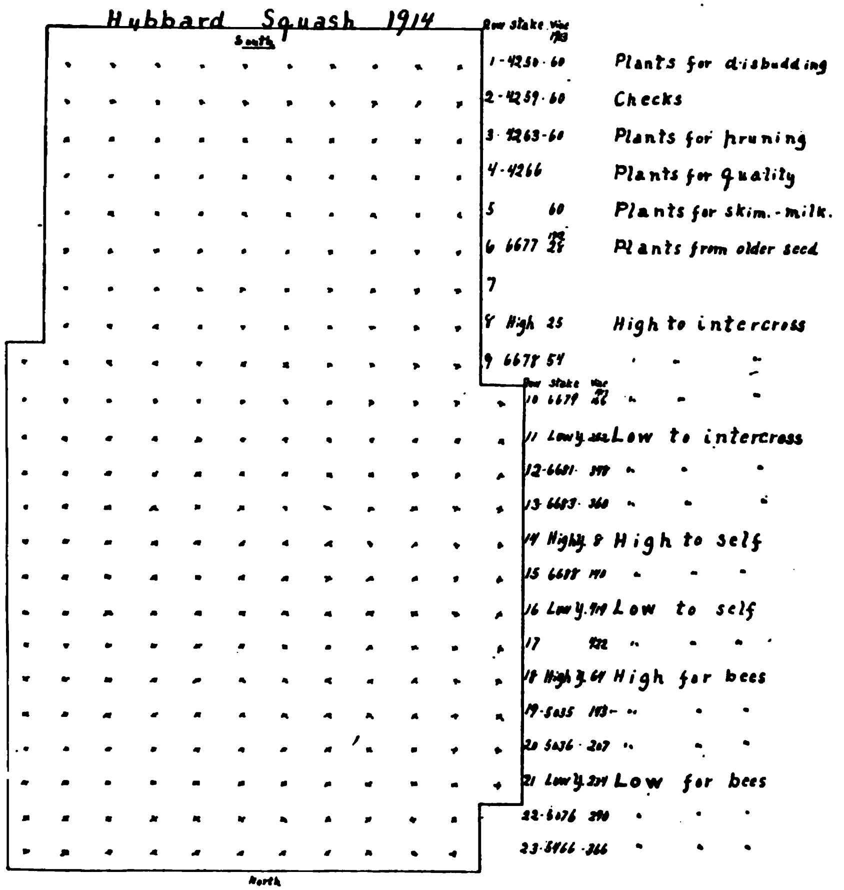
Hubbard Squash 1914
South
Row stake Vine
1-4250-60 Plants for disbudding
2-4259-60 Checks
3-4263-60 Plants for pruning
4-4266 Plants for quality
5 60 Plants for skim.-milk.
6 6677 28 Plants from older seed
7
8 High 25 High to intercross
9 6678 54
Row stake Vine
10 6679
11 Low y. Low to intercross
12-6681
13-6683-360
14 High y. 8 High to self
15 6688
16 Low y. Low to self
17
18 High y. 64 High for bees
19-5035
20 5036-207
21 Low y. Low for bees
22-5076
23-5466-366
North

Chart of experimental field in 1914 showing different kinds of treatment for influence on yield.

In 1916 the high-yielding plants produced 31 percent more and the low-yielding plants 1 percent more than the check. It is not clear why the latter result occurred. Possibly the check lot was derived from an especially good ancestry.

Since three consecutive years of self-fertilization did not tend to lessen the yield, it seems fair to conclude that the immediate effect of self-fertilization on production is negligible. The ultimate effect of continuous self-fertilization is a matter that lies beyond the range of this publication. It is important to note, however, that notwithstanding self-pollination, it is possible to segregate for the time being and to maintain either high- or low-producing vines or both, the seed being selected on the basis of past yields. This means that the yield of squashes is determined in part by the ability of a plant to project its yielding propensities to its progeny. In other words it is a matter of transmission and inheritance.

## INFLUENCE OF INTER-CROSSING

Some of the plants were inter-crossed, a process in which fertilization is effected by pollen derived from a plant having the same immediate parent, as that which bears the pistils to be fertilized. That this process is less restricted than self-pollination seems to be indicated by the greater vigor and fertility of the resulting plants compared with those that were self-fertilized. In inter-crossing there is some chance for stimulation due to the individual differences. Comparisons are found in the following table:

YIELDS OF INTER-CROSSED PLANTS

| Year | Nature of yield | Number of plants | Average yield, pounds | Percentage gain or loss over check | |
|---|---|---|---|---|---|
| 1914 | Check | 139 | 16.7 | ... | |
| | High | 52 | 27.2 | +62.9 | |
| | Low | 72 | 17.8 | + 6.6 | |
| 1915 | Check 1 | 125 | 23.4 | Check 1 | Check 2 |
| | Check 2 | 20 | 21.0 | .. | .. |
| | High | 64 | 22.2 | —5.1 | +5.7 |
| | Low | 68 | 22.1 | —5.6 | +5.2 |
| 1916 | Check | 155 | 16.2 | ... | |
| | High | 116 | 23.4 | +44.4 | |
| | Low | 103 | 15.3 | — 5.6 | |

The decided gain made in 1914 by the high-yielding plants—63 percent—is significant in contrast to the slight gain made by the inter-crossed low yielders—7 percent. The spread of the "highs" over the "lows" is 53 percent. Comparing these yields with the 1914 selfed plants as shown in the table, it is clear that the inter-crossed plants were somewhat the more productive of the two.

The 1915 results were striking but inexplicable. Check 1 is the average of both high and low and check 2 represents a mixture of seed taken at random. The high-yielding plants were less productive by 5 percent and the low by 6 percent than were the check 1 plants and more productive by 6 and 5 percents, respectively, than the check 2 plants.

In 1916 the yields showed great contrasts, the high-producing plants exceeding the checks by 44 percent, while the low-producing plants were exceeded by the checks to the extent of 6 percent.

Apparently inter-crossing did not affect yields. Seed selection on the basis of previous production seems more likely than inter-crossing to be the controlling factor. A difference in vegetative vigor of the whole plant might account for the increase.

## SEED SELECTION FROM OPEN-POLLINATIONS

The results of seed selection from plants that were fertilized by insects, as normally happens, are set forth below by way of contrast with the results secured in other ways. Since 1911, selections have been based upon the yields of the preceding year. From year to year careful records have been kept of the yield performance of certain plants. Much of the earlier data, including 1911 and 1912, were secured in connection with another trial wherein high- and low-yielding plants were grown in individual plats. The yield of these plants with results from 1913 to 1916 are brought together below:

YIELDS OF OPEN-POLLINATED PLANTS

| Year | Series | Number of vines | Average yield, pounds | Percentage gain or loss over low |
|---|---|---|---|---|
| 1911 | High | 161 | 11.2 | —8.9 |
| | Low | 55 | 12.3 | .. |
| 1912 | High | 102 | 12.6 | +31.3 |
| | Low | 76 | 9.6 | ... |
| 1913 | High | 177 | 15.3 | +29.7 |
| | Low | 143 | 11.8 | ... |
| 1914 | High | 71 | 22.2 | +101.8 |
| | Low | 68 | 11.0 | .... |
| 1915 | High | 64 | 27.2 | +40.9 |
| | Low | 61 | 19.3 | ... |
| 1916 | High | 119 | 23.3 | +26.6 |
| | Low | 98 | 18.4 | ... |

In 1911 the high-yielding lot was exceeded by its competitor to the extent of 9 percent, but from 1912 onwards the high-yielding plants remained in the lead, outstripping their rivals; in 1912 by 31 percent, in 1913 by 30 percent, in 1914 by 102 percent, in 1915 by 41 percent, and in 1916 by 27 percent. The greatest benefit secured by this method of selection was reached after three years. The anomalous result secured in 1911 in reality was only seemingly incongruous. As a matter of fact it took two years in which definitely to isolate the two strains.

The following table shows the average gains in yields of squash per vine of the high-yielding over the low-yielding strains, the differences between the two strains for the three years and the influence on yields of the methods of pollination. The 1914 average yield of all the plants of the high-yielding was 60 percent greater than that of the low-yielding strain, in 1915, 22 percent, and in 1916, 37 percent.

No marked differences in yields were observed which seemed attributable to the method of pollination. However, in general it appeared that the nearer one approached the open or natural method of pollination in procedure, the greater was the yield. The average three-year yield of the open-pollinated plants was about 12 percent greater than that of either the inter-crossed or self-pollinated plants as appears in the following table, the selfed percentage being 33, the inter-crossed 34, the open-pollinated 46. The superiority of the high-yielding over the low-yielding strain, regardless of the method of pollination, is clear, the average three-year gain being 37 percent.

SUMMARY OF COMPARATIVE YIELDS

Weight of squashes per vine

| Year | Percentage gain of high over low | | | |
|---|---|---|---|---|
| | Self-fertilized | Inter-crossed | Open-pollinated | Weighted average |
| 1914 .............. | 43 | 53 | 102 | 60 |
| 1915 .............. | 30 | 1 | 41 | 22 |
| 1916 .............. | 29 | 53 | 27 | 37 |
| Weighted average.. | 33 | 34 | 46 | 37 |

A more ready comparison may be secured both as to treatment of the blossoms and the year of the crop under consideration from the table showing the combined results for three years.

COMBINED RESULTS—THREE YEARS

Weight of squash per vine

| Treatment | Series | Number of plants | Average yield, pounds | Percentage gain of high over low |
|---|---|---|---|---|
| Self-fertilized | High | 181 | 23.2 | +32.7 |
| | Low | 213 | 17.5 | ... |
| Inter-crossed | High | 232 | 23.9 | +33.5 |
| | Low | 243 | 17.9 | ... |
| Open-pollinated | High | 254 | 24. | +46.3 |
| | Low | 227 | 16.4 | ... |

COMBINED RESULTS—THREE TREATMENTS

| Year | | | | |
|---|---|---|---|---|
| 1914 | High | 171 | 23.9 | +60.4 |
| | Low | 188 | 14.9 | ... |
| 1915 | High | 172 | 25.5 | +22. |
| | Low | 181 | 20.9 | ... |
| 1916 | High | 324 | 22.8 | +36.5 |
| | Low | 314 | 16.7 | ... |
| Grand total | High | 667 | 23.7 | +37. |
| | Low | 683 | 17.3 | ... |
| | Check | 439 | 18.6 | ... |

These marked differences extending through several seasons point strongly to the probable occurrence of high- and low-producing forms. The high remain relatively high and the low remain relatively low, notwithstanding the probable greater or less intermixture of these open-pollinated plants. It seems fair to conclude that seed selection on the basis of yield is the most important means of segregating and maintaining plants of either low- or high-producing forms. In fact it is remarkable that this should be so, entirely irrespective of how pollination was effected. In a word, much can be accomplished by simple and straight selection. One needs merely to know the definite yields of parental plants for a few years in order to proceed intelligently; and it should be remembered that it is as important to avoid the low as it is to select the high.

## COOPERATIVE TRIALS IN STRAIGHT SELECTION

In order to extend the trials in seed selection and to check the results obtained under different conditions, three Vermont horticulturists, Messrs. E. H. Hallett of St. Johnsbury, Luther Putnam of Cambridge and C. W. Stone of Springfield, volunteered to plant the seed and to keep careful yield records. The results secured by these gentlemen are shown below and obviously furnish additional testimony as to the advisability of seed selection.

1912 YIELDS

| Name of cooperator | Series | Number of vines | Average yield, pounds | Percentage gain high over low |
|---|---|---|---|---|
| Hallett | High | 12 | 44.3 | 103 |
| | Low | 12 | 21.8 | ... |
| Putnam | High | 10 | 24.4 | 72 |
| | Low | 10 | 14.2 | ... |
| Stone | High | 12 | 17.9 | 167 |
| | Low | 12 | 6.7 | ... |

The high-yielding strains outclassed the low-yielding strains by from 72 to 167 percent. These results, though highly variable, were comparable with and paralleled those secured on the University Farm.

The following table combines the results of three years' work—1914 to 1916—selecting from the high- and low-yielding parent plants.

COMPARISON OF YIELDS—WEIGHT OF FRUIT PER VINE

| | | High | | Low | | Check | | |
|---|---|---|---|---|---|---|---|---|
| Year | Treatment | Number of plants | Average yield | Number of plants | Average yield | Number of plants | Average yield | Gain high over low |
| | | | lbs. | | lbs. | | lbs. | % |
| 1914 | Self-fertilized | 48 | 22.8 | 48 | 15.9 | ... | ... | 43. |
| | Inter-crossed | 52 | 27.2 | 72 | 17.8 | ... | ... | 53 |
| | Open-pollinated | 71 | 22.2 | 68 | 11.0 | 139 | 16.7 | 102 |
| | | 171 | 23.9 | 188 | 14.9 | 139 | 16.7 | 60 |
| 1915 | Self-fertilized | 44 | 27.6 | 52 | 21.3 | ... | ... | 30 |
| | Inter-crossed | 64 | 22.2 | 68 | 22.1 | ... | ... | 1 |
| | Open-pollinated | 64 | 27.2 | 61 | 19.3 | ... | ... | 41 |
| | | 172 | 25.5 | 181 | 20.9 | 20 | 21. | 22 |
| 1916 | Self-fertilized | 89 | 21.2 | 113 | 16.4 | ... | ... | 29 |
| | Inter-crossed | 116 | 23.4 | 103 | 15.3 | ... | ... | 53 |
| | Open-pollinated | 119 | 23.3 | 98 | 18.4 | ... | ... | 27 |
| | | 324 | 22.8 | 314 | 16.7 | 159 | 16.2 | 37 |

## GAIN PER ACRE IN SEED SELECTION

In order to show what the value of selection would be to a commercial grower, the yields obtained have been compared on an acreage basis. If the hills are planted 10 feet apart each way, three vines to a hill, there would be about 1,300 vines to an acre.

ESTIMATED YIELD OF SQUASHES PER ACRE

**Three-year average**

| | Strain | Number of squashes | Weight of squashes | Weight per squash |
|---|---|---|---|---|
| | | | lbs. | lbs. |
| Average per vine........ | High | 2.09 | 24.05 | 11.50 |
| | Low | 1.80 | 16.65 | 9.25 |
| Yield per acre .......... | High | 2,717 | 31,265 | .... |
| | Low | 2,340 | 21,645 | .... |
| Gain for high ........... | | 377 | 9,620 | 2.25 |
| Percent gain for high.... | | 12% | 44% | 24.3% |

If these 1,300 vines to the acre were open-pollinated and if they had yielded the average crop of the three years, 1914 to 1916, the high-yielding strain would have produced 31,265 pounds and the low-yielding strain 21,645 pounds per acre, a gain of 9,620 pounds per acre as a result of the use of selected seed. The high-producing vines would have grown 2,717 and the low-producing vines 2,340 squashes, a gain of 377 fruit per acre in favor of the former. Twelve percent more squashes, weighing 44 percent more, the average individual squash being a fourth heavier, represents the net result.

## STATISTICAL STUDIES IN VARIATION

A more technical study of variation was made with reference to changes in weight of squashes per vine and weight per squash under the different treatments. These data are presented in statistical form in the following tables, covering the seven years from 1911 to 1917.

A comparison of the effect of the different treatments is made more precise by the use of the mean, the standard deviation, coefficient of variability, and the average deviation, terms defined below.

Several interesting points may be deduced. After 1911, when anomalous results were secured, the mean for the "high" presented an advantageous contrast to that for the "low." It reached its maximum in 1916, when in the northern section it approximated 33.09 in the high open-pollinated plants. The mean for the low of that year in this section was 26.62, or 6.47 pounds less per vine than for the high. The mean for the low reached its nadir in 1912 when it was only 9.66 pounds per vine. The standard deviation for the high in contrast to

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**NOTE.**—The *mean* is the average for the group. It is taken as a basis, and from it the *standard deviation* is ascertained by squaring the deviations before multiplying them by their respective frequencies. The standard deviation therefore offers a reliable basis for comparing characters under consideration. In this particular instance it is the weight of fruits per vine in the differently treated groups of squashes. As compared to the average deviation, the standard deviation gives greater value to extreme variations. Squaring the deviations, accentuates their value.

The *average deviation* is the amount of deviation of the different groups of individuals from the mean. It is an index of the amount of variability. It is determined by obtaining first the amount which each class varies from the mean, and then, by multiplying each deviation thus obtained by the number of individuals in that class.

The *coefficient of variability* is an abstract expression combining the idea of standard deviation and type. It is determined by dividing the standard deviation by the means as a base. The result is an index of variability expressed in percent. The coefficient of variability affords an accurate means of comparing directly the variability of one frequency distribution with that of another, no matter what the character, whether in the same or different individuals. By means of this coefficient, the breeder may not only ascertain whether one character is more variable than another, but by taking this coefficient frequently, as, for instance, for the same variety under different seasons or conditions, he can know the variability of a character as influenced by time or circumstances. By these calculations it is possible to ascertain if progress is being made.

All of the calculations for the mean, the standard deviation, the coefficient of variability, and the average deviation, and also their probable errors were carried out to four decimal places. For the sake of conciseness, however, two of these decimal places were eliminated in making up the tables. As the weights made in the field were not accurate beyond one-twentieth of a pound, it would be of little use to consider anything beyond one one-hundredth of a pound.

WEIGHT STATISTICS—Weight of fruits per vine

| Series | Mean (pounds) | Standard deviation | Coefficient of variability | Average deviation |
|---|---|---|---|---|
| 1911 | | | | |
| High .......... | 10.69 ± .28 | 5.18 ± .20 | 48.41 ± .26 | 4.22 |
| Low ........... | 12.50 ± .49 | 5.35 ± .35 | 42.77 ±3.25 | 4.37 |
| 1912 | | | | |
| High .......... | 12.79 ± .37 | 5.61 ± .26 | 43.85 ±2.43 | 4.20 |
| Low .......... | 9.66 ± .39 | 5.07 ± .28 | 52.49 ±2.31 | 4.10 |
| 1913 | | | | |
| High .......... | 15.35 ± .34 | 6.74 ± .24 | 43.88 ±1.86 | 5.12 |
| Low ........... | 11.92 ± .29 | 5.14 ± .20 | 43.12 ±2.02 | 4.16 |
| Commercial check No. 2.. | 12.74 ± .49 | 4.95 ± .36 | 38.88 ±3.07 | 3.70 |
| 1914 | | | | |
| Inter-crossed | | | | |
| High ........ | 26.77 ±1.43 | 15.32 ±1.01 | 57.18 ±4.87 | 11.00 |
| Low ......... | 17.89 ± .84 | 10.56 ± .59 | 59.01 ± .32 | 8.45 |
| Self-pollinated | | | | |
| High ........ | 22.88 ± .94 | 9.70 ± .67 | 42.41 ±3.40 | 7.19 |
| Low ......... | 16.04 ± .74 | 7.46 ± .51 | 46.51 ±3.74 | 6.09 |
| Open-pollinated | | | | |
| High ........ | 22.20 ± .74 | 9.17 ± .52 | 41.29 ±2.71 | 7.43 |
| Low ......... | 11.00 ± .50 | 6.15 ± .36 | 55.91 ±4.12 | 4.91 |
| Check (No. 1) | 16.72 ± .54 | 9.49 ± .38 | 56.74 ±2.94 | 8.17 |
| 1915 | | | | |
| Inter-crossed | | | | |
| High ........ | 24.07 ±1.42 | 13.67 ±1.01 | 56.78 ±5.35 | 11.08 |
| Low ......... | 22.53 ± .84 | 10.23 ± .59 | 45.41 ±3.12 | 8.59 |
| Self-pollinated | | | | |
| High ........ | 27.73 ±1.53 | 15.03 ±1.08 | 54.21 ±5.03 | 11.81 |
| Low ......... | 21.43 ± .90 | 9.50 ± .64 | 44.34 ±3.50 | 7.90 |
| Open-pollinated | | | | |
| High ....... | 27.28 ±1.21 | 14.30 ± .85 | 52.42 ±4.44 | 12.11 |
| Low ......... | 19.44 ± .90 | 10.43 ± .64 | 53.66 ±4.11 | 8.46 |
| Check (No. 1) | 23.46 ± .78 | 12.97 ± .55 | 55.30 ±2.99 | 10.82 |
| 1916 Southern section | | | | |
| Inter-crossed | | | | |
| High ........ | 22.32 ±1.13 | 12.98 ± .80 | 58.12 ±4.62 | 10.46 |
| Low ......... | 14.90 ±7.46 | 7.82 ± .53 | 52.47 ±4.43 | 6.29 |
| Self-pollinated | | | | |
| High ........ | 13.54 ± .93 | 8.39 ± .66 | 61.92 ±6.46 | 6.47 |
| Low ......... | 11.98 ± .60 | 6.68 ± .43 | 55.76 ±4.53 | 5.30 |
| Open-pollinated | | | | |
| High ........ | 14.23 ± .65 | 7.51 ± .46 | 52.75 ±4.02 | 5.47 |
| Low ......... | 11.85 ± .67 | 7.24 ± .47 | 61.06 ±5.29 | 5.25 |
| 1916 Northern section | | | | |
| Inter-crossed | | | | |
| High ........ | 24.64 ±1.40 | 15.56 ± .99 | 62.85 ±5.36 | 11.14 |
| Low ......... | 15.64 ± .91 | 9.84 ± .65 | 62.88 ±5.51 | 8.00 |
| Self-pollinated | | | | |
| High ........ | 26.81 ±1.90 | 20.26 ±1.34 | 75.58 ±7.32 | 16.70 |
| Low ......... | 21.11 ±1.05 | 11.71 ± .74 | 55.49 ±4.45 | 5.08 |
| Open-pollinated | | | | |
| High ........ | 33.09 ±1.55 | 16.96 ±1.06 | 51.26 ±3.97 | 7.18 |
| Low ......... | 26.62 ±1.44 | 14.68 ±1.02 | 55.17 ±4.87 | 12.37 |

the low did not show material advantage till 1913, when it was 6.74 as compared with 5.14 for the low. In the other years (1914-1917) it exceeded the low by relatively large margins. The average deviation for high and low ran nearly parallel during 1911 and 1912, began to diverge in 1913 and became quite marked in 1914, especially in the inter-crossed group, good contrasts occurring during the last three years. The check groups were usually intermediate between high and low.

WEIGHT STATISTICS—*Concluded*—Weight of fruits per vine

| Series | Mean (pounds) | Standard deviation | Coefficient of variability | Average deviation |
|---|---|---|---|---|
| **1916 Both sections, combined** | | | | |
| **Inter-crossed** | | | | |
| **High** ........ | 23.44 ± .90 | 14.30 ± .63 | 61.00 ±3.56 | 10.88 |
| **Low** ......... | 15.12 ± .62 | 9.14 ± .59 | 60.42 ±3.81 | 7.50 |
| **Self-pollinated** | | | | |
| **High** ........ | 21.29 ±1.26 | 17.66 ± .89 | 82.96 ±6.46 | 13.81 |
| **Low** ......... | 16.57 ± .67 | 10.59 ± .48 | 63.96 ±3.87 | 8.61 |
| **Open-pollinated** | | | | |
| **High** ........ | 23.42 ±1.01 | 16.27 ± .71 | 69.45 ±4.26 | 13.85 |
| **Low** ......... | 18.79 ± .92 | 13.61 ± .64 | 72.43 ±4.94 | 10.87 |
| **1917** | | | | |
| **Open-pollinated** | | | | |
| **High** ........ | 17.44 ± .62 | 12.44 ± .43 | 71.28 ±2.86 | 9.14 |
| **Low** ......... | 13.39 ± .36 | 8.35 ± .19 | 62.32 ±2.31 | 6.23 |

In 1916 it became necessary to enlarge the squash plantation to permit of somewhat more extensive plantings of certain groups. In this connection it is well to note the probable correlation between more food and moisture coupled with greater variability and a higher mean. The new land was greensward, naturally, somewhat richer and more retentive of moisture. At the time the computations were made it seemed desirable to differentiate between the results secured on the original area and upon the new land. Hence results from the 1916 and later crops are so tabulated as to enable one to discriminate between the northern (new) and the southern (old) sections. As the tables show, means were higher and variability greater on the newer area.

In general it is to be noted that the means have increased for the high yielders in the various plots from year to year until 1916; and, since the mean for the low yielders remains low, the selections have been producing results. On account of the great variability and the increase in value of means, new values must have been coming in representing extreme variations within the group of high-yielding plants. Among the low-producing forms there was not much change in the value of the mean prior to 1916 when some increase occurred.

In all the selections made it was apparent that the work was in the direction of natural variation but greatly intensified. The variability as shown by the coefficient was increased rather than decreased.

## WEIGHT OF INDIVIDUAL SQUASHES

Squashes vary likewise in respect to the weight of individual specimens pollinated according to different methods. Data were col-

WEIGHT OF INDIVIDUAL FRUITS

| Series | Mean (pounds) | Standard deviation | Coefficient of variability | Average deviation |
|---|---|---|---|---|
| 1913 | | | | |
| High .......... | 10.93 ± .18 | 4.27 ± .13 | 39.12 ±1.35 | 3.40 |
| Low ........... | 8.34 ± .16 | 3.46 ± .12 | 41.42 ±1.60 | 2.85 |
| Check (No. 2) | 9.82 ± .30 | 3.50 ± .22 | 35.60 ±2.45 | 2.76 |
| 1914 | | | | |
| Inter-crossed | | | | |
| High ........ | 10.77 ± .35 | 5.94 ± .25 | 55.16 ±2.90 | 4.91 |
| Low ......... | 8.63 ± .23 | 4.19 ± .16 | 48.51 ±2.29 | 3.29 |
| Self-pollinated | | | | |
| High ........ | 8.69 ± .26 | 4.29 ± .18 | 49.38 ±2.55 | 3.28 |
| Low ......... | 10.17 ± .29 | 3.78 ± .21 | 37.18 ±2.30 | 3.11 |
| Open-pollinated | | | | |
| High ........ | 11.39 ± .34 | 5.94 ± .24 | 52.18 ±2.62 | 4.43 |
| Low ......... | 7.73 ± .20 | 2.96 ± .14 | 38.32 ±2.11 | 2.38 |
| Check (No. 2) | 9.90 ± .23 | 5.26 ± .16 | 53.13 ±2.07 | 4.00 |
| 1915 | | | | |
| Inter-crossed | | | | |
| High ........ | 12.07 ± .42 | 5.71 ± .30 | 47.32 ±3.14 | 4.53 |
| Low ........ | 10.50 ± .20 | 3.53 ± .14 | 33.58 ±1.49 | 2.74 |
| Self-pollinated | | | | |
| High ........ | 9.30 ± .23 | 3.81 ± .16 | 41.02 ±1.97 | 2.96 |
| Low ........ | 11.20 ± .26 | 3.87 ± .18 | 34.58 ±1.84 | 3.03 |
| Open-pollinated | | | | |
| High ........ | 13.07 ± .32 | 5.33 ± .22 | 40.83 ±1.94 | 4.19 |
| Low ......... | 9.06 ± .17 | 3.72 ± .20 | 41.06 ±1.98 | 2.74 |
| Check (No. 1) | 11.31 ± .21 | 5.09 ± .15 | 45.01 ±1.58 | 4.00 |
| 1916 | | | | |
| Inter-crossed | | | | |
| High ........ | 9.77 ± .22 | 5.48 ± .16 | 56.01 ±2.05 | 4.44 |
| Low ......... | 8.17 ± .17 | 3.54 ± .12 | 43.35 ±1.80 | 2.82 |
| Self-pollinated | | | | |
| High ........ | 6.53 ± .13 | 3.19 ± .09 | 48.90 ±1.65 | 2.60 |
| Low ......... | 9.35 ± .20 | 4.02 ± .14 | 48.47 ±2.03 | 3.21 |
| Open-pollinated | | | | |
| High ........ | 10.82 ± .19 | 4.42 ± .13 | 40.87 ±1.40 | 3.89 |
| Low ......... | 10.18 ± .18 | 3.50 ± .13 | 34.51 ±1.37 | 3.30 |
| 1917 | | | | |
| Self-pollinated | | | | |
| High ........ | 8.05 ± .12 | 3.43 ± .08 | 42.59 ±1.15 | 2.77 |
| Low ........ | 10.80 ± .19 | 4.86 ± .13 | 44.94 ±1.46 | 3.96 |
| Open-pollinated | | | | |
| High ........ | 8.03 ± .22 | 3.98 ± .16 | 49.53 ±2.40 | 3.09 |

lected from 1913 to 1917, inclusive. The weights of fruit per vine, the mean or average, standard deviation, and the coefficient of variability and the average deviation were determined. The weight of individual fruits is the basis for the computations which are given in the subjoined tables.

The data of variability on the weights of individual fruit for five years may be briefed as follows:

The mean for those from high-yielding parents was greater than that for the low- in 1913, and also for the inter-crossed and high-open-pollinated groups of 1914, 1915 and 1916; but the mean of those from high-yielding parents was less than that for the low- in the case of the low-self-pollinated series of 1914, 1915, 1916 and 1917. It appears that the method of pollination was effective and that it was more potent than the method of seed selection. Self-pollination had the effect of reducing the mean of the high yielders or of increasing the mean for the low.

The standard deviation was greater for the high yielders as compared to the low, for 1913, 1914, 1915, 1916, except in the self-pollinated sets of 1915, 1916 and 1917. Self-pollination was again operative. The data for average deviation gave parallel results.

The coefficient of variability data showed no consistent status. It was less for the high in 1913 and 1917, and greater in 1914-1916.

The check lots were intermediate with respect to the mean, standard deviation, average deviation, and the coefficient of variability.

In brief, the outcome of selecting the highs for a series of years was to increase their weights up to certain limits, except in the case of the self-pollinated plants whose lows seem to be superior. The individual fruits of the high-yielding plants were larger.

## NUMBER OF SQUASHES PER VINE

How does the method of pollination influence the number of fruits per vine? Computations were made during the years 1914 to 1917. The following tables show the effect of different methods of pollination on the number of squashes produced:

NUMBER OF FRUITS PER VINE

| Series | Mean | Standard deviation | Coefficient of variability | Average deviation |
|---|---|---|---|---|
| 1914 | | | | |
| Inter-crossed | | | | |
| High ........... | 2.54 ± .13 | 1.42 ± .09 | 55.96 ±4.72 | 1.16 |
| Low ............ | 2.08 ± .10 | 1.21 ± .07 | 58.10 ±4.23 | .92 |
| Self-pollinated | | | | |
| High .......... | 2.65 ± .12 | 1.25 ± .09 | 47.23 ±3.91 | 1.06 |
| Low ............ | 1.58 ± .08 | .79 ± .05 | 49.65 ±4.17 | .68 |
| Open-pollinated | | | | |
| High .......... | 1.96 ± .06 | .78 ± .04 | 39.69 ±2.58 | .57 |
| Low ............ | 1.43 ± .05 | .67 ± .04 | 47.12 ±3.27 | .57 |
| Check .......... | 1.70 ± .05 | .85 ± .03 | 49.98 ±2.48 | .66 |
| 1915 | | | | |
| Inter-crossed | | | | |
| High ........... | 2.00 ± .12 | 1.13 ± .08 | 56.67 ±5.34 | .90 |
| Low ............ | 2.16 ± .09 | 1.05 ± .06 | 48.64 ±3.42 | .79 |
| Self-pollinated | | | | |
| High ........... | 3.00 ± .19 | 1.87 ± .13 | 62.36 ±5.98 | 1.41 |
| Low ............ | 1.92 ± .09 | .95 ± .06 | 49.52 ±4.00 | .78 |
| Open-pollinated | | | | |
| High ........... | 2.13 ± .08 | 1.02 ± .06 | 47.77 ±3.44 | .80 |
| Low ............ | 2.16 ± .09 | 1.06 ± .06 | 46.82 ±3.43 | .76 |
| Check .......... | 2.14 ± .06 | 1.01 ± .04 | 47.50 ±2.44 | .78 |
| 1916 | | | | |
| Inter-crossed | | | | |
| High ........... | 2.43 ± .10 | 1.64 ± .07 | 67.46 ±4.10 | 1.17 |
| Low ............ | 1.90 ± .06 | .86 ± .04 | 45.13 ±2.52 | .68 |
| Self-pollinated | | | | |
| High ........... | 3.30 ± .17 | 2.42 ± .12 | 73.27 ±3.89 | 1.70 |
| Low ............ | 1.70 ± .06 | .91 ± .41 | 53.65 ±3.02 | .73 |
| Open-pollinated | | | | |
| High .......... | 2.16 ± .08 | 1.23 ± .05 | 57.09 ±3.21 | 1.05 |
| Low ............ | 1.86 ± .07 | 1.01 ± .05 | 54.07 ±3.26 | .82 |
| 1917 | | | | |
| Self-pollinated | | | | |
| High ........... | 2.24 ± .08 | 1.64 ± .06 | 73.08 ±3.79 | 1.14 |
| Low ............ | 1.27 ± .03 | .64 ± .02 | 50.58 ±1.86 | .55 |
| Open-pollinated | | | | |
| High .......... | 1.77 ± .09 | 1.25 ± .07 | 70.48 ±5.24 | 1.53 |

The highest mean was found with the self-pollinated, high-yielding plants in each of the four years, which shows that the greatest number of fruits is secured in accordance with this treatment. Indeed, self-pollinating the high-yielding plants produced more fruit than did any other treatment, although the high-yielding, inter-crossed plants were not greatly inferior in this respect.

It should be remembered in this connection, however, as is shown elsewhere (page 20), that this treatment also averaged a smaller weight per vine than did other treatments. In general the same statement holds in comparing the data for standard deviation. None of the other methods of blossom treatment gave factors which show any degree of uniformity during the three years under consideration.

## NUMBER OF BLOSSOMS AND NUMBER OF SQUASHES

It was thought that there might be some relation between the number of blossoms formed and the number of fruits that developed. Do high-yielding plants produce more flowers than low-yielding ones? If this is the case, is there some inter-relation between the number of blossoms and the quantity of fruit? Information was collected as to these points during 1915. The flowers on high- and on low-yielding squash plants were counted in July and August for the whole blossoming period.

BLOSSOM DATA OF HIGH- AND LOW-YIELDING PLANTS

| Series | Number of vines | NUMBER OF FLOWERS All flowers average per vine | Male flowers average per vine | Female flowers average per vine | Ratio male to female |
|---|---|---|---|---|---|
| High-yielding | 177 | 20.4 | 16.3 | 4.1 | 4. to 1 |
| Low-yielding | 143 | 24.9 | 21.2 | 3.7 | 5.7 to 1 |

The low-yielding plants averaged to produce 22 percent more total blossoms than did the high-yielding plants, 30 percent more staminate, but 10 percent less pistilate flowers. Thus one might infer that the low-producing plants were unable to set as many pistillate blossoms as were the high-yielding plants; however, in reality, they produced more fruit as computed and shown in the table. There would seem to be no apparent or necessary correlation between blossom numbers and fruit yields. Indeed there seems to be no limit to the number of blossoms which may be formed on a squash plant, except that set by frost.

## EFFECT OF PRUNING ON PRODUCTION

It is characteristic of squashes, as it is of other cucurbits, to continue growth, to form blossoms and to set fruit until very late in the season. This habit generally results in the production of many immature squashes. These are not merely waste in themselves but they draw upon the general food supply of the plant. Could not the energy thus wasted in producing superfluous branches and late formed fruits be devoted to the greater development and finer perfection of the early set squashes? Could not rampant vine growth and late set blossoms be prevented or lessened?

Certain pruning experiments were started in order to test the practicability of pruning squash plants, by cutting back the ends of rapidly growing vines and removing the late formed blossoms. The pruning and disbudding operations were conducted separately, so that the effect of each procedure upon the outcome could be definitely determined.

The pruning consisted simply in cutting off the ends of the vines about two feet beyond the point of the second or third developing fruit. The effect of this treatment is shown below in contrast to the production of unpruned vines.

EFFECT OF PRUNING THE VINES

| Year | Treatment | Number of vines | Average yield pounds | Percent loss or gain pruned over check |
|---|---|---|---|---|
| 1913 | check | 20 | 12.2 | |
| | pruned | 19 | 13.6 | +11.1 |
| 1914 | check | 20 | 46.1 | |
| | pruned | 20 | 43.6 | — 5.4 |
| 1915 | check | 20 | 29.2 | |
| | pruned | 20 | 20.2 | —30.8 |

In 1913 an 11 percent gain appeared, but in 1914 and 1915 losses of 5 and 31 percents occurred. Vines grow mostly from the end. If growing parts are removed little subsequent growth occurs wherewith to support the accumulated burden that follows the setting of early squashes. As is shown elsewhere, a positive correlation exists between the number of leaves per plant and the production of fruits. This may explain these unfavorable results. When many leaves are cut away the assimilative capacity of the plant is materially reduced. A vine cannot produce large yields without abundant foliage. In view of these facts, it seems clear that vine pruning can have no beneficial effect but, on the contrary, is likely to prove harmful.

Disbudding, as practiced, involves the removal of late formed buds. The Hubbard produces an astonishing amount of pollen, the average number of male flowers per plant during the season being about 80. A staminate flower produces on the average 0.05 grams of pollen. An acre, two plants per hill, would carry: planted 9 x 9, 9.6 pounds; 10 x 10, 7.8 pounds; 12 x 12, 5.4 pounds; 15 x 15, 3.5 pounds. This abundance may well suggest wastage of plant resources, notwithstanding the fact that liberal supplies are necessary. Pollen is a very rich substance, containing a high percentage of albuminous material. If this surplus could be transferred to the growth of the fruits with corresponding reduction in number, the total yield might be materially increased. Disbudding operations began when two or three fruits had set, after which staminate buds and flowers were cut away. These operations resulted in a gain over the check plants, as appears below:

RESULTS OF DISBUDDING

| Year | Treatment | Number of vines | Average weight of fruit per vine | Gain for disbudding |
|---|---|---|---|---|
| | | | lbs. | % |
| 1913 | check | 20 | 12.2 | ..... |
| | disbudded | 20 | 15.4 | +26.2 |
| 1914 | check | 20 | 46.1 | ..... |
| | disbudded | 20 | 47.0 | + 2. |

The disbudded plants exceeded the checks in average yield by 27 percent in 1913, and by 2 percent in 1914. Disbudding did not involve much work, although for a time daily attention was required. Under intensive methods of culture, a limited amount of disbudding may prove worth while.

## CORRELATION IN NUMBER OF LEAVES AND WEIGHT OF FRUITS

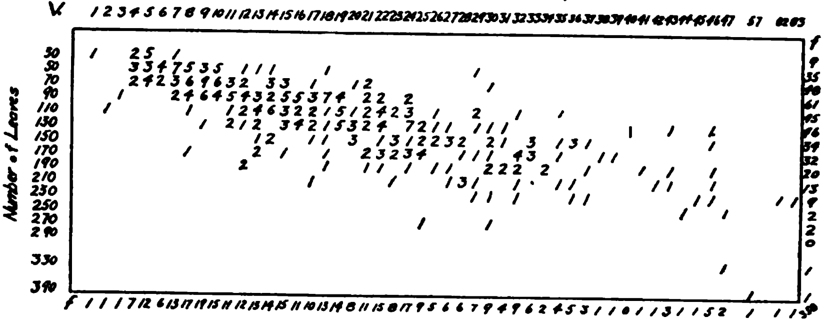
Correlation refers to that interrelation between separate characters by which they tend in some degree at least to move together. Thus, if an increase in one character is always followed by a corresponding and proportional increase in a related character, the correlation is said to be perfect, and the ratio is 1. On the other hand, if an increase in one character is followed by a corresponding and proportional decrease in a related character, the correlation is said to be negative, and the ratio is —1, or perfect negative correlation.

The several steps in the process of computing the correlation are as follows: The populations were arrayed in the correlation table so there would be two sets of frequencies; one as to the number of leaves, and one as to weight of fruit. For each of these the means and average deviations were calculated. Then the number in each square of the correlation table is taken and multiplied by each corresponding deviation in both weight and number. Finally the probable error of the determined values is ascertained.

A determination on the possible correlation between the number of leaves and the weight of fruit per vine gave positive results. Counts of leaves, and weighings of fruits were made. The correlation tables are as given below. The data on correlation show a close interrelation of the number of leaves and weight of fruits. In 1914

Correlation of Number of Leaves and Weight of Fruit per Vine

1914 Crop Weight of Fruit per Vine in pounds



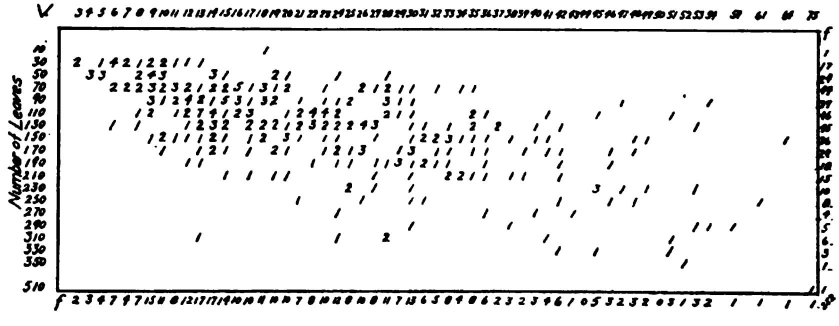
Number of Leaves
Mean 119274 ± 1957
Standard Deviation 55.692 ± 1383

Weight of Fruit
Mean 19.226 ± 407
Standard Deviation 11.339 ± 288.

Coefficient of Correlation .742 ± .016

1915 Crop Correlation of Number of Leaves and Weight of Fruit per Vine 1915 Crop

Weight of Fruit per Vine in Pounds



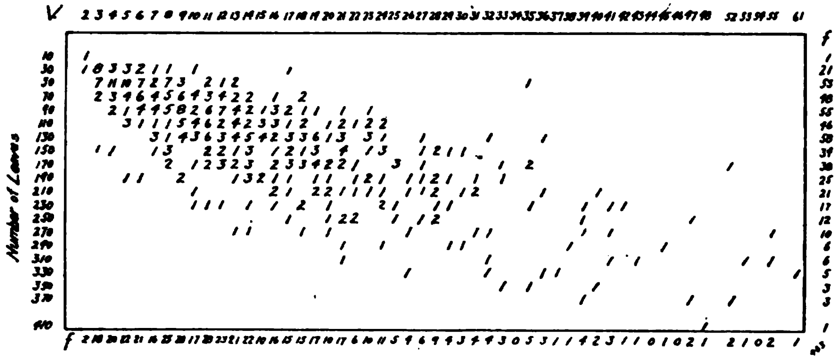
Number of Leaves
Mean 132.557 ± 2.521
Std. Dev 70.908 ± 1.782

Weight of Fruit
Mean 23.176 ± .478
Std. Dev 13.370 ± .338

Coefficient of Correlation .610 ± .023

1916 Crop — Correlation of Number of Leaves and Weight of Fruit per Vine — 1916 Crop

Weight of Fruit per Vine in Pounds

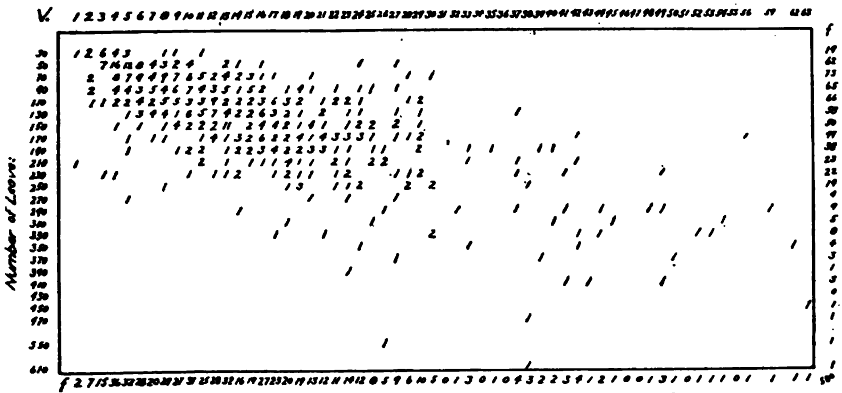


| Number of Leaves | | Weight of Fruit | |
|---|---|---|---|
| Mean | 134.665 ± 2.356 | Mean | 15.666 ± .322 |
| Std.Dev. | 75.156 ± 1.666 | Std. Dev. | 10.041 ± .228 |

Coefficient of Correlation .793 ± .012

1917 Crop — Correlation of Number of Leaves and Weight of Fruit per Vine — 1917 Crop

Weight of Fruit per Vine in Pounds



| Number of Leaves | | Weight of Fruit | |
|---|---|---|---|
| Mean | 102.095 ± 2.301 | Mean | 15.130 ± .291 |
| Std. Dev. | 82.290 ± 1.628 | Std. Dev. | 10.384 ± .206 |

Coefficient of Correlation .718 ± .014

the correlation was .742 ± 0.16; in 1915 it was .610± .023; in 1916 it was .793 ± .012; and in 1917 it was .718 ± 0.14. Such positive and parallel correlations for four consecutive years afford valid evidence of the interrelationship of the number of leaves and the weight of fruit produced. The correlation data should be taken into account in connection with the data on pruning which are presented elsewhere (p. 24). It is reasonable to expect correlations between the number of leaves and the crop produced, since leaves are the great assimilative organs of the plant. In general, then, the more leaves, the better nourished the plant may be and the greater its possible output of squashes. The biological explanation of the correlation may be on the basis of vigor of the plant. The stronger and more vigorous the growth, the quicker the plant initiates its "grand period" of growth. An abundance of early foliage might, therefore, ultimately result in the production of more fruits. Early advantages are of value in increasing the crop for the year.

## CONTROL OF QUALITY IN HUBBARD SQUASH

It is generally believed that all varieties of squashes possess distinct characteristics of quality. Among absolutely pure varieties this is probably true, but few if any squashes in reality are pure and true to their varietal characteristics. Within almost any lot there doubtless exists more or less impurity, due to admixtures which arise because of the open pollination of the flowers and the cross fertilization of fruits. There is undoubted mixture among closely allied forms, such as Hubbard, Butman and Delicious, and it is common to find many non-typical specimens within a supposedly pure lot of any of these varieties. In fact many gardeners are unable to identify a typical Hubbard for the simple reason that they seldom see one.

## THE HUBBARD TYPE

What is a Hubbard squash? How may its characteristics be described? In answering the foregoing questions, it is well to refer to the original description as given by the late J. J. H. Gregory of Marblehead, Mass., who wrote "The form of the Hubbard is spherical at the middle, gradually receding to a neck at the stem end, and to a point usually curved at the calyx end where it terminates in a kind of button or acorn. In color it is dark green, excepting where it rests on the ground, where it is of an orange color. It usually has streaks of dirty white beginning at the calyx end where the ribs meet, and extending from one-half to two-thirds the way to the stem."

The forms generally known as Hubbard, if true to type, are dark green, and are to be distinguished from blue-forms, of which the Middleton Blue was probably the ancestral blue parent; from the Delicious which is smaller and smoother than the Hubbard; from the Butman which has a skin of a grassy green intermixed with white; from the Warted Hubbard which has a rough and warty surface due to small protuberances which form on the shell; and, finally, from the Golden Hubbard which has a salmon red shell when ripe. The Warted Hubbard is larger and keeps longer than the Smooth Hubbard, perhaps because of its harder and more impervious shell. Most of the commercial Hubbards grown today are more or less impure and exhibit some of the characteristics of the closely allied forms listed above. The warting is of frequent occurrence on many Hubbards and may be either poorly or well developed.

## STRUCTURE OF HUBBARD

The squash is properly called a fruit, although known botanically as a "pepo." The marketable product is the ripened ovary, with the ovules matured to seeds, with the periphery, the exocarp and mesocarp, gorged with food, and the exterior of the exocarp hardened to a shell. Within the fleshy pericarp is located the spongy, fibrous and unpalatable placenta bearing the seeds. Quality is much influenced by the abundance and coarseness of the placental fibres which extend into and through the flesh. The preservation of a squash, as well as its quality, is associated with the hardness and thickness of the shell, which is a commercial asset since it permits long distance shipments. The shell thickness seems correlated with high quality. Measurements show variations ranging from 0.025 as a minimum to 0.25 as a maximum with an average of 0.137 inches. Thick shelled squashes are usually of extra good quality, although the Warted Hubbards may be exceptions in this respect. Thick and hard shells are associated with ripeness of squash.

The flesh is subject to marked variations in respect to color, thickness, flavor, texture, moisture and quality. Its normal and typical color is yellowish orange. In passing from the shell inward towards the placenta, it deepens from a pale yellow to a clear orange, especially in thick-fleshed and well-ripened specimens. This color differentiation is associated with quality differentiation. The thickness of the flesh also is variable, careful measurements indicating variations from 0.6 to 3.1 with an average of 1.47 inches. A thick-fleshed squash is preferable to a thin-fleshed fruit since it contains a relatively larger proportion of edible product. Thickness of flesh, however, is not always associated with fine quality.

## QUALITY OF HUBBARDS

There is much difference in the flavor and quality of squashes. Some are sweet and nutty, some are mild, some are strong flavored, some taste much like pumpkin. Most Hubbards are sweet, pleasant and palatable, although one often finds insipid or strongly unpleasant and distinctly unpalatable specimens. Insipidity is characteristic of immature or of long stored squashes. The texture, either raw or cooked, is by no means constant. Texture represents a composite of granulation and fibrination. Careful comparative analysis of the physical structure enables one to note marked textural differences. Some specimens are dry and mealy, as well as sweet and palatable; others are coarsely granular or even lumpy. Moderate size granules are to be preferred. A too finely granular flesh usually results in a pasty or salvy product. Proper granulation imparts good texture to the flesh.

A flesh reasonably free from moisture, dry and mealy, is usually held to be ideal. The number of strings or fibro-vascular bundles composing the placenta and permeating the flesh modify its texture according to their size, toughness and general abundance. Some squashes are quite fibrous and stringy, while others contain only a few fibers which are soft, small and melting. The proportion of fibers appearing in the finished dish is determined in part by the care exercised in cutting or scraping the placental portion from the firm flesh and in part by the nature of the specimen. In tests made in connection with these studies, care was taken to remove from each specimen a uniform portion of placenta that was not too closely interwoven with the flesh and therefore not involving wastage of flesh. However, even when these precautions were observed, certain specimens were found in which so many fibers had penetrated the flesh that the final product was of inferior quality.

Hubbards vary greatly in respect to their moisture content. Some are wet, others are dry and mealy. The latter characteristic is the desired one. In common with other vegetables, squash contains much water. Texture, flavor and quality of the flesh are better near the shell than towards the center. The flesh at the outermost periphery is sweeter and more granular than that at the innermost periphery. That this is so was testified to in several instances by five different and unwarned persons. The samplers in each instance supposed that they were passing judgment on the quality of different squashes rather than upon that of different layers of flesh from the same specimen. Furthermore, this verdict was substantiated by chemical analyses with special reference to sugar content. A test was made with reference to moisture and sugar differences in three layers of flesh beginning inside next to the placenta and extending to the shell. A slice of flesh from a squash was divided into six sections. Three of the uncooked alternate sections were taken representing three layers, which, upon analysis gave the following differences: Inner portion of flesh 92.78 percent moisture and 7.22 percent dry matter; middle portion 92.95 percent moisture and 7.05 percent dry matter; outer portion 92.39 percent and 7.61 percent dry matter.

The remaining three sections were steam cooked, and three corresponding layers of flesh were analyzed for moisture and sugar content with results as follows:

MOISTURE AND SUGAR CONTENT IN INNER AND OUTER FLESH

| | Moisture | Reducing sugars | Sucrose | Total sugar |
|---|---|---|---|---|
| | % | % | % | % |
| Inner portion ........ | 91.01 | 3.09 | 0.57 | 3.66 |
| Middle portion ........ | 90.78 | 4.42 | 0.47 | 4.89 |
| Outer portion ........ | 89.93 | 4.79 | 0.63 | 5.42 |

The outer flesh carried half as much again total sugars as did the inner portion, the middle portion being intermediate. The dry matter of the inner flesh contained 40 percent of the sugars and of the middle and outer parts 53 percent. The water content of the inner flesh was higher than that of the outer by 1.08 percent, with the middle flesh intermediate.

Many poor specimens were found during the early quality testing spect to palatability that their moisture and sugar content were determined. One was quite moist and of poor quality; the other was dry, sweet and of good quality. The outer and inner portions of the flesh of each specimen were separated after having been steam cooked and analyzed with results as follows:

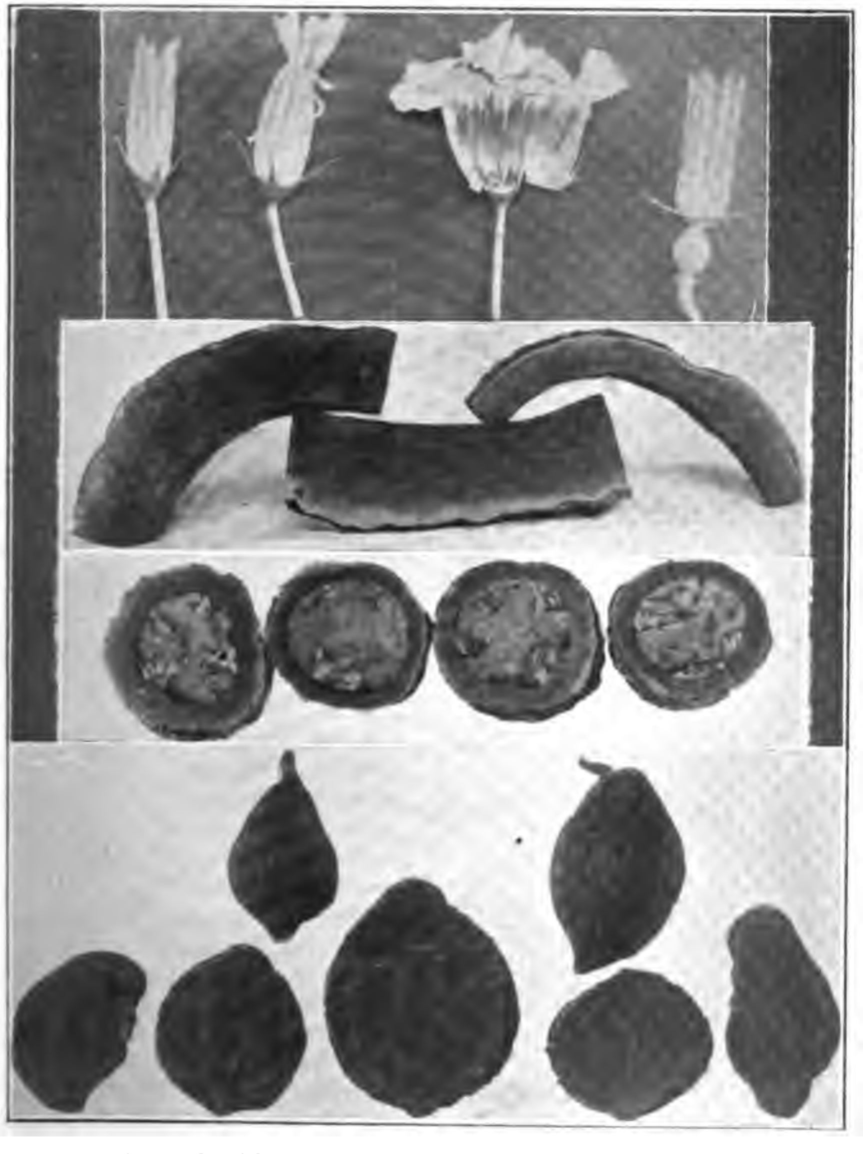
GOOD AND POOR QUALITY SQUASHES, MOISTURE AND SUGAR CONTENT

| | Moisture<br>% | Reducing sugars<br>% | Sucrose<br>% | Total sugar<br>% |
|---|---|---|---|---|
| Poor quality | | | | |
| Inner flesh....... | 89.65 | 3.16 | 0.46 | 3.62 |
| Outer flesh....... | 89.76 | 2.85 | 0.34 | 3.19 |
| Average ......... | 89.70 | 3.00 | 0.40 | 3.41 |
| Good quality | | | | |
| Inner flesh....... | 87.55 | 4.31 | 0.86 | 5.17 |
| Outer flesh....... | 86.21 | 4.63 | 1.21 | 5.84 |
| Average ......... | 86.88 | 4.47 | 1.04 | 5.50 |

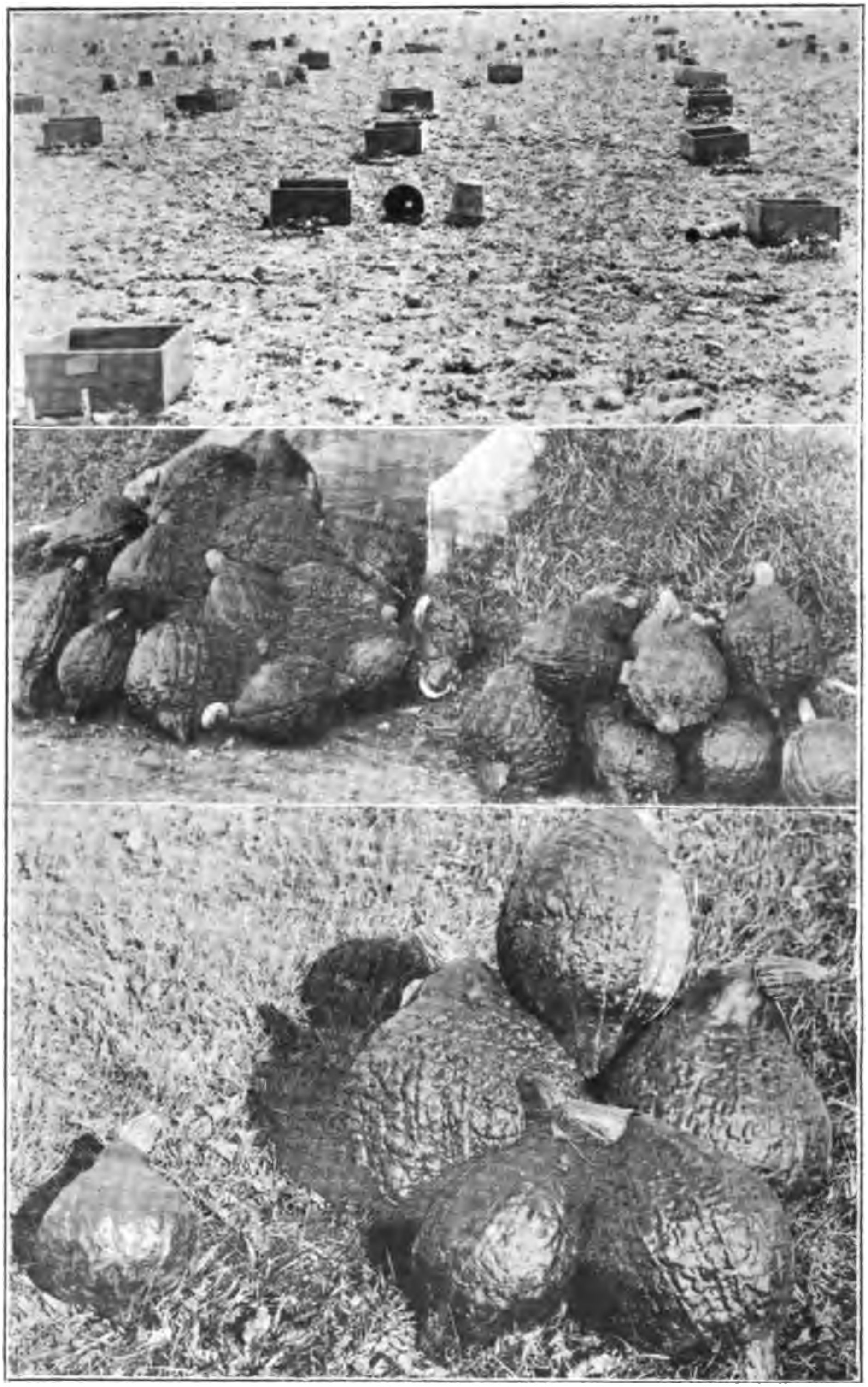
The specimen of poor quality carried 2.82 percent more moisture, 1.47 percent less reducing sugars, 0.64 percent less sucrose and 2.09 percent less total sugars than the specimen which was of good quality. These figures throw some light on the question of what constitutes good quality in Hubbard squashes and led to the more extensive studies as to the relationship between chemical composition and quality in squash discussed on pages 40 to 47.

Many years ago Gregory said, "Squash should be cooked by steam rather than by hot water and should be served on the shell." Since the most nutritious and palatable portion of the flesh is near the shell, it should be scraped clean, regardless of how the product is served, thus insuring the largest amount of the most nutritious and pleasant tasting portion.

Obviously many factors enter into the determination of quality in squashes. In general, however, it may be said that it is decided chiefly by the chemical composition and especially by the content of sugars and starches which give flavor and food value to the fruit; and to a considerable extent by the structure of its flesh which is composed of fibers and granules which by their number, sizes and toughness, give it character and, finally, in part by the moisture content. Satisfactory quality in squashes is seldom if ever found unless associated with pleasant flavor and proper texture, suitable water content and an abundant sugar percentage, good granulation or a tolerable amount of fibers, as necessary complements. Quality, then, is a generic and all embracing term.



Flowers of squash with staminate at left, and pistillate at right.
Sections of flesh and shell to show line of demarkation in ripe specimens in middle, and no line at left in unripe squash.
Cross sections of squashes showing differences in thickness of flesh.
Shapes and surface marking of Hubbards showing lack of trueness to type. All seed from same source. Second specimen at left in bottom row is the only true Hubbard in the lot.



Transplanted squash plants, three weeks old when set out, showing also pots in which they were grown and boxes used as covers to protect against frost.
Relative yields, high and low producing plants.
Variation in yields per vine.

## CONTROL OF QUALITY

To what extent may quality be controlled by seed selection? The samples of squashes that were used in the trials were steam cooked and tested for quality. In recording judgment attention was given to flavor; to moisture; to texture as shown by granulation and fibrination; and, finally, to quality as a summation. The tests were conducted throughout each winter from 1915 to 1920 inclusive, sampling and testing beginning in November and continuing at weekly intervals for a considerable period. An idea of the nature of the physical analysis at the time of testing is given on the accompanying table which shows the distribution of the quality factors. These scores were assembled regardless the nature of the strain or their previous status. The table lists the number of specimens and the percentage total for each year, under the headings of fibrination, granulation, moisture, flavor and quality. For instance, in 1915, 19 percent of the specimens tested were very fibrous; 36 percent were merely fibrous; 33 percent were medium fibrous; 12 percent were slightly fibrous and none were abso-

DISTRIBUTION FACTORS OF QUALITY
ALL STRAIN COMBINED

| Grade | No. spec. | % | No. spec. | % | No. spec. | % | No. spec. | % |
|---|---|---|---|---|---|---|---|---|
| | 1915 | | 1916 | | 1917 | | 1918 | |
| | | | FIBRINATION | | | | | |
| Very fibrous | 26 | 19 | 7 | 8 | 7 | 3 | 6 | 2.2 |
| Fibrous | 49 | 35.8 | 26 | 20.7 | 74 | 31.6 | 116 | 43.4 |
| Medium | 45 | 32.8 | 12 | 27.6 | 55 | 23.5 | 28 | 10.5 |
| Few | 17 | 12.4 | 24 | 13.8 | 17 | 7.3 | 87 | 32.6 |
| None | .. | .... | 18 | 29.8 | 81 | 34.6 | 30 | 11.2 |
| | | | GRANULATION | | | | | |
| Very fine | 22 | 16.1 | 2 | 2.3 | 133 | 56.8 | 63 | 23.6 |
| Fine | 35 | 25.6 | 48 | 55.2 | 24 | 10.3 | 62 | 23.2 |
| Medium | 48 | 35 | 27 | 31 | 67 | 28.6 | 78 | 29.2 |
| Coarse | 29 | 21.2 | 9 | 10.3 | 9 | 3.8 | 64 | 24 |
| Very coarse | 3 | 2.2 | 1 | 1.1 | 1 | .4 | .. | .... |
| | | | MOISTURE | | | | | |
| Dry | 50 | 36.5 | 33 | 37.9 | 44 | 18.8 | 69 | 25.8 |
| Medium | 63 | 46 | 45 | 51.7 | 143 | 61.1 | 122 | 45.7 |
| Wet | 19 | 13.9 | 8 | 9.1 | 43 | 18.4 | 76 | 28.5 |
| Very wet | 5 | 3.6 | 1 | 1.2 | 4 | 1.7 | .. | .... |
| | | | FLAVOR | | | | | |
| Excellent | 3 | 2.2 | 2 | 2.3 | .. | .... | 37 | 13.9 |
| Very good | 8 | 5.8 | 2 | 2.3 | 3 | 1.3 | 80 | 29.9 |
| Good | 51 | 37.2 | 52 | 59.8 | 126 | 53.8 | 70 | 15 |
| Fair | 37 | 27 | 12 | 13.8 | 33 | 14.1 | 19 | 7.1 |
| Poor | 38 | 27.8 | 19 | 21.8 | 72 | 30.8 | 91 | 34.1 |
| | | | QUALITY | | | | | |
| Excellent | 12 | 8.8 | 18 | 20.7 | 8 | 3.4 | 15 | 5.6 |
| Very good | 20 | 14.6 | 13 | 14.9 | 36 | 15.4 | 40 | 15 |
| Good | 33 | 24.1 | 24 | 27.6 | 87 | 37.2 | 84 | 31.5 |
| Fair | 41 | 29.9 | 16 | 18.4 | 41 | 17.5 | 71 | 26.6 |
| Poor | 31 | 22.6 | 16 | 18.4 | 62 | 26.5 | 57 | 21.3 |

lutely fiberless. The extent of the variations in the other factors is shown in the headings that were adopted for the classification.

## SEED SELECTION AND QUALITY

Preliminary quality studies were made from the 1914 crop. Seeds from four poor squashes, and five good ones were used. The number and quality of their progeny in 1915 is given in the table below:

INFLUENCE OF PARENTS ON QUALITY OF PROGENY

| Quality in 1914 | Squash | Quality of progeny in 1915 | | | | | |
|---|---|---|---|---|---|---|---|
| | | Excellent | Very good | Good | Fair | Poor | Total |
| Poor | A | ... | ... | 3 | 2 | 7 | 12 |
| | B | ... | ... | ... | 1 | 3 | 4 |
| | C | ... | ... | ... | ... | 2 | 2 |
| | D | ... | ... | 2 | 1 | ... | 3 |
| | Total | ... | ... | 5 | 4 | 12 | 21 |
| | Percentage | ... | ... | 24 | 19 | 57 | 100 |
| Good | E | 1 | ... | 1 | 2 | 1 | 5 |
| | F | 1 | ... | ... | ... | ... | 1 |
| | G | 1 | ... | ... | ... | ... | 1 |
| | H | ... | ... | 1 | 1 | ... | 2 |
| | I | 1 | ... | 9 | 7 | ... | 17 |
| | Total | 4 | ... | 11 | 10 | 1 | 26 |
| | Percentage | 15 | ... | 42 | 39 | 4 | 100 |

Of the squashes derived from poor quality parents none were very good or excellent, 42 percent were good, 39 percent fair, and 4 percent poor. These first results were very suggestive of three things: First, the probable importance of good heritage; second, the apparent undesirable combination of quality factors; and, third, the need of studying quality inheritance. In view of these observations, more extensive trials were instituted in 1915 and continued for five years.

In 1915, 137 squashes were sampled for quality; in 1916, 87; in 1917, 234; and in 1918, 267; in 1919, 95; and in 1920, 132; a total of 952 specimens. Beginning with the crop of 1915, four quite distinct strains were employed to ascertain the possible control of quality by seed selection as based upon the edibility tests. The particulars of these types are given herewith:

## INHERITANCE OF QUALITY IN FOUR STRAINS

No. 773. Tests extended over four years. In 1915 a squash specimen, 98, was tested and characterized as being moderately moist, with a coarse granulation having many fibers, poor in flavor, but fair in quality. In 1916, three progeny specimens, 179, 181 and 182, were tested and found to be slightly fibrous, finely granular, medium to dry in moisture, sweet in flavor, and good to excellent in quality. Specimen 181, which was the parent for the 1917 crop, was a medium sized specimen, greenish brown in color, with mottled, but indistinct rays and a smooth exterior. The shell was 0.15 inch in thickness, hard and brittle. The flesh was light orange in color with no green, 1.4 inches thick, dry, mealy, of good texture, sweet and excellent in quality. Of the 1917 progeny 38 specimens were tested; 5 being excellent; 16 very good; 13 good; 3 fair; and 1 poor. The good specimens were to the poor in the ratio of 8 to 1. Strain 773 ranked good in 1916, and also in 1917. Its tested progeny in 1918 gave 6 excellent specimens; 13 very good; 19 good; 14 fair; and 13 poor; 58 percent being good or better and 42 percent fair or poor in quality. The use of this strain was discontinued in 1919.

No. 270 was of good quality. Its original parent was tested February 4, 1916, and recorded as granular, slightly fibrous in texture, dry, fair in flavor and only fair in quality. Of the 1916 crop, 5 specimens were tested, all being medium coarse in granulation, slightly fibrous, moderately dry in flesh, while the flavor of all but one was good, two being excellent, one very good, one good and one poor in quality. Specimen 205 was classed as good in quality, was chosen as the parent for the 1917 crop, and 37 of its progeny were tested in the winter of 1917-18, 1 being excellent, 13 very good, 13 good, 6 fair and 4 poor in quality. The extremes were rare, the means (good and very good) greatly in the majority. In the 1918 crop strain 270 produced 8 specimens that were excellent; 16 very good; 16 good; 16 fair; and 9 poor. In the 1919 crop it produced 26 excellent specimens; 23 that were very good; 16 good; 11 fair; and 5 poor ones. In the 1920 crop there were 7 excellent squashes; 14 very good; 14 good; 4 fair; and no poor ones. Strain 270 was obviously a good sort for in three successive years it produced of good or better and of fair to poor progeny, respectively, 61 and 39 percents; 80 and 20 percents; and 90 and 10 percents.

No. 31 was chosen for quality tests because of its large size and its flesh characters which contrasted well with those of strain 270. It was specimen 205 of the 31 strain of the crop of 1916, weighed 14¼ pounds and was the only fruit on the vine. It was globular in shape, rough on the exterior, without rays, and light grayish-green, almost yellow in color. Its shell was hard, brittle and thin, measuring 36 mm. in thickness and its flesh orange in color, fine in texture and very fibrous, quite moist, sweet and palatable. It scored "good" in quality. Forty-six specimens of the 1917 crop were tested. None were deemed excellent; 6 were held to be very good; 22 good; 10 fair; and 8 poor. Not a single fruit possessed that desirable combination of dryness and sweetness together with agreeable texture and good flavor necessary for admittance among the "excellent."

In the 1918 crop, 49 specimens were set aside for quality tests, which graded 5 very good; 17 good; 20 fair; and 7 poor. The fair and poor ones were wet, coarse in texture or unpalatable in flavor. Of the 1919 crop none were excellent; only two were deemed to be very good; 10 good; 53 fair; and 35 were poor. In the 1920 crop, none were excellent; one was held to be very good; 7 good; 11 fair; and 27 were poor. The percentage statements for the 4 years were: good or better, 61, 45, 12 and 17; fair or poor, 39, 55, 88 and 83. The fact that there was not a single excellent specimen grown in five years suggests that the right combination of factors for good quality was unattainable. It was not there. The attributes of sweetness, dryness and good texture did not appear in this strain.

No. 531 was poor at the outset and continued to be poor throughout four years. It was chosen to contrast with 773. In 1915 it was described as small, round, nearly smooth with narrow greenish rays extending from stem to apex. The flesh was very wet, fine grained, and stringy, poor in flavor and in quality. The offspring in the crop of 1916 were poor in quality. The 1917 crop consisted of 5 mature specimens graded as 2 fair and 3 poor. The 1918 crop bore 88 specimens which the quality basis graded 1 excellent; 6 very good; 32 good; 21 fair; and 28 were poor, 44 percent being good or better and 56 percent fair to poor. There was but one really fine specimen, 28 were not fit to eat and 21 were scarcely edible. Unpleasant flavor, excessive strands and fibers or extreme wetness were the discounting factors. This strain was discontinued in 1919.

*Check series.* The 1919 check lot was grown from purchased seed and, therefore, was of unknown quality. It so happened that 69 percent of its progeny were good. Of the 80 specimens tested, 12 were excellent; 28 very good; 15 good; 15 fair; 7 poor; and 2 green. The quality of the fruit raised from commercial seed may be either good or poor and the chances are equal. This lot happened to have good parents and, consequently, much of the fruit was of fine quality, comparing well with strain 270 (page 35). A second year such seed might yield squashes to a considerable extent resembling strain 31 (pages 37-38).

The 1920 check lot derived from the 1919 check series yielded 4 excellent squash; 11 very good; 20 good; 10 fair; and 2 poor fruit, 74 percent being good or better and 26 percent inferior in respect to quality. The check lot was intermediate between 270, a good strain, and 31, a poor one. For purposes of ready comparison, the quality of the tests are assémbled in a connected table.

Quality Records for Four Years

|  | Year of crop | Number squashes tested | Excellent | Very good | Good | Fair | Poor |
|---|---|---|---|---|---|---|---|
|  |  | % | % | % | % | % | % |
| Strain | 1915 | 1 | ... | ... | 100 | ... | ... |
| 270 | 1916 | 1 | 100 | ... | ... | ... | ... |
|  | 1917 | 32 | 3 | 34 | 41 | 19 | 3 |
|  | 1918 | 48 | 11 | 27 | 33 | 21 | 8 |
|  | 1919 | 68 | 37 | 32 | 22 | 6 | 3 |
|  | 1920 | 39 | 18 | 36 | 36 | 10 | ... |
| Strain | 1915 | 1 | ... | ... | ... | ... | 100 |
| 31 | 1916 | 1 | ... | ... | ... | ... | 100 |
|  | 1917 | 7 | ... | ... | 14 | 43 | 43 |
|  | 1918 | 40 | ... | 10 | 35 | 42 | 13 |
|  | 1919 | 81 | ... | 2 | 10 | 54 | 34 |
|  | 1920 | 46 | ... | 2 | 15 | 24 | 59 |
| Strain | 1915 | 1 | ... | ... | ... | 100 | ... |
| 773 | 1916 | 1 | 100 | ... | ... | ... | ... |
|  | 1917 | 30 | 23 | 50 | 27 | ... | ... |
|  | 1918 | 68 | 13 | 27 | 27 | 19 | 14 |
| Strain | 1915 | 1 | ... | ... | 100 | ... | ... |
| 531 | 1916 | 1 | ... | ... | ... | ... | 100 |
|  | 1917 | 20 | ... | ... | 30 | 10 | 60 |
|  | 1918 | 79 | 1 | 10 | 37 | 25 | 27 |
| Strain | 1915 | 1 | ... | ... | 100 | ... | ... |
| 900 | 1916 | 1 | ... | ... | 100 | ... | ... |
|  | 1917 | 45 | ... | 13 | 49 | 22 | 16 |
| Check | 1919 | 67 | 18 | 40 | 24 | 15 | 3 |
|  | 1920 | 47 | 9 | 23 | 43 | 21 | 4 |

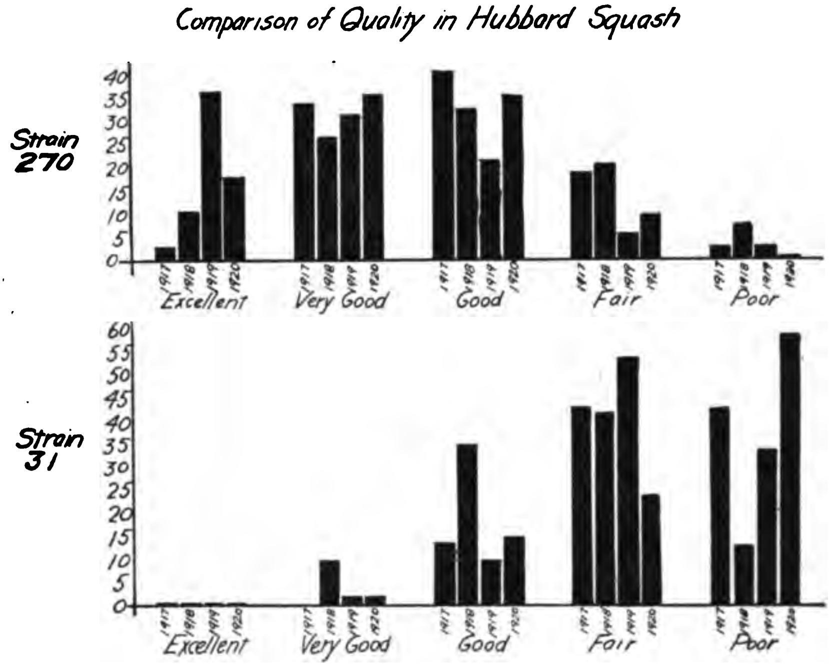


Chart to show comparison of quality in two complementary strains of selected Hubbards over a period of four years.

In an endeavor to sum up concisely the quality of the various strains of squashes for each year, so that comparisons could be readily made, an arbitrary value which might be called an "index of quality" was computed. The following values were given to the different classes:

| Class | Excellent | Very Good | Good | Fair | Poor |
|---|---|---|---|---|---|
| Value | 2 | 1 | 0 | —1 | —2 |

The percentage in each class was multiplied by the value assigned to that class. The algebraic sum of the resulting figures was used as an index of quality. An index of zero indicates that the squashes as a whole were of average or "good" quality; a plus sign a variation better than average quality; and a minus sign a variation in quality inferior to the average. For example, if the entire produce of a strain graded "very good," the index would be +100; if fair, —100.

The following table shows the index of quality of the several strains for four years:

INDEX OF QUALITY

| Strain | 1917 | 1918 | 1919 | 1920 | Average |
|---|---|---|---|---|---|
| 270 | 15 | 12 | 94 | 62 | 46 |
| 31 | —129 | —56 | —120 | —140 | —111 |
| 773 | 96 | 6 | ... | ... | 51 |
| 531 | —130 | —67 | ... | ... | — 99 |
| 900 | — 41 | .. | ... | ... | — 41 |
| Check | ... | .. | 55 | 12 | 34 |

For the most part the strains bred true to their ancestors with respect to quality. They were pedigree cultures and nearly if not quite pure line squashes. They conformed to general expectations in progeny tests. The 270 projected much of its good quality, and 31 much of its poor quality to their respective progeny.

The two strains numbered 270 and 31 were quite distinct in size, shape and surface markings, and could be easily distinguished in the field at harvest time. The 270 strain is much smaller than the 31, has a smoother shell, blossoms earlier and matures a little earlier than the 31. Several other strains were discovered, but were not preserved.

Clearly, quality is largely controllable by seed selection. There is a strong tendency for the progeny to resemble their parents in quality. The use of seed from a good parent is likely to result in a large percentage of good offspring. Quality characters are inherent in the breed although not entirely controllable by seed selection. Within certain limits, and without too great precision, it may be said that quality characters are transmissible.

An explanation of the apparent inability absolutely to control quality should take into account two sets of factors; one internal, the other external. All squashes are probably more or less mixed in their parentage on account of cross- and open-pollination. Since quality is a generic rather than a specific term, it may be hybrid in physical constitution and include some mutually exclusive attributes. Some squashes were found to be sweet, yet strong in flavor; others were dry and mealy, yet slightly acid; and still others were coarsely granular, abundantly and unpleasantly fibrous, yet sweet and dry. Some were known to be the product of crosses between good and poor parents. Admitting, then, the probable intermixture of several quality attributes of a strain, and the uncertainty of the number of generations necessary to "purify and fix" a character or set of characters, the reasons why quality may be somewhat beyond control are obvious, even though self-pollination is effected and all intercrossing prevented.

One must make also some allowance for the influence of soil and weather, since these factors limit growth and maturity. The soil used in these trials was good, although scarcely ideal. The 1918 summer was short, cold and wet and high quality and maturity were unattainable; indeed in some Vermont counties no winter squashes reached full maturity and ripeness that year. In view of the controlling effect of these two internal and external factors, it is really quite remarkable that such definite results were secured in the selection experiments.

It seems clear that one may propagate almost at will either a strain of poor quality or of good quality and that the characteristics of the parent squash and its immediate ancestors in the main determine the grade of the progeny. Most commercial seed stock is protean in nature and quality; but by continued seed selection and self-fertilization, quality, good or poor, can be promptly isolated and a desirable strain established.

## QUALITY AND CHEMICAL COMPOSITION

The probable relation of quality to chemical composition was early recognized. In order to ascertain just what relationship existed between good and poor quality squashes in respect to composition, correlation studies were made dealing with tests of edibility and chemical analyses. Every fruit tested for quality from 1915 to 1919 was analyzed for dry matter and crude protein and complete analyses made of composite samples.

The following tables show the average analyses for each of the five quality groups, and, likewise, for the different series of strains under trial and experimental control. Only ripe and fully mature squashes were tested, all specimens which at harvest or subsequently were deemed green being excluded.

The figures clearly indicate the interrelation between good quality on the one hand and water and crude protein contents on the other. The super-average product contained less water than that of poor quality which carried a relatively large water percentage. The squashes graded "excellent" contained from 80 to 84 percent water, averaging 82 percent during the five years; those graded "poor" from 87 to 91 percent, averaging for five years 89 percent. The intermediate grades in respect to quality were intermediate also in respect to their water content.

### QUALITY AND CHEMICAL ANALYSES

Five Year Averages—Arranged in Groups on Basis of Quality

| | Year | Number of squashes | Original material | | Protein in dry matter |
|---|---|---|---|---|---|
| | | | Water | Protein | |
| | | | % | % | % |
| **Excellent** | 1915 | 11 | 82.74 | 1.88 | 10.89 |
| | 1916 | 18 | 85.06 | 1.84 | 12.32 |
| | 1917 | 8 | 79.62 | 2.15 | 10.56 |
| | 1918 | 15 | 83.67 | 1.91 | 11.69 |
| | 1919 | 38 | 81.34 | 2.09 | 11.20 |
| **Very good** | 1915 | 21 | 85.32 | 1.75 | 11.92 |
| | 1916 | 14 | 87.33 | 1.80 | 14.21 |
| | 1917 | 33 | 83.11 | 1.74 | 10.30 |
| | 1918 | 43 | 86.50 | 1.60 | 11.85 |
| | 1919 | 51 | 83.27 | 2.00 | 11.95 |
| **Good** | 1915 | 36 | 86.21 | 1.71 | 12.40 |
| | 1916 | 24 | 88.29 | 1.65 | 14.09 |
| | 1917 | 79 | 87.43 | 1.30 | 10.34 |
| | 1918 | 77 | 88.92 | 1.35 | 12.18 |
| | 1919 | 39 | 85.99 | 1.79 | 12.78 |
| **Fair** | 1915 | 37 | 86.48 | 1.61 | 11.91 |
| | 1916 | 15 | 88.39 | 1.55 | 13.35 |
| | 1917 | 35 | 88.43 | 1.20 | 10.37 |
| | 1918 | 60 | 89.29 | 1.41 | 13.17 |
| | 1919 | 59 | 88.30 | 1.62 | 13.85 |
| **Poor** | 1915 | 31 | 87.17 | 1.53 | 11.92 |
| | 1916 | 16 | 88.87 | 1.78 | 15.99 |
| | 1917 | 44 | 89.17 | 1.17 | 10.80 |
| | 1918 | 40 | 90.69 | 1.24 | 13.32 |
| | 1919 | 31 | 87.27 | 1.84 | 14.45 |

SUMMARY

| | Number of squashes | Water | Protein | Protein in dry matter |
|---|---|---|---|---|
| **Excellent** | 90 | 82.49 | 2.00 | 11.36 |
| **Very good** | 162 | 84.71 | 1.79 | 11.71 |
| **Good** | 255 | 87.57 | 1.47 | 11.83 |
| **Fair** | 206 | 88.29 | 1.48 | 12.64 |
| **Poor** | 162 | 88.77 | 1.44 | 12.82 |
| **Average** | | 86.91 | 1.58 | 12.07 |

Similar correlations existed between quality and protein content. The dry matter of the squashes classed as poor quality contained a greater percentage of protein than did those of better quality. The protein of the fruit graded "excellent" on a dry matter basis varied from 10.54 to 11.69 percent and averaged for five years 11.36 percent, whereas the protein of the fruit graded "poor" ranged from 10.80 to

### QUALITY AND CHEMICAL ANALYSES

**Five Year Averages—Arranged in Groups of Five Strains**

| | | Number of squashes | Original material | | Protein in dry matter |
|---|---|---|---|---|---|
| Strain | Year | | Water | Protein | |
| | | | % | % | % |
| 270+ | 1915 | 1 | 81.68 | 2.28 | 12.44 |
| | 1916 | 1 | 85.91 | 1.75 | 12.42 |
| | 1917 | 32 | 86.35 | 1.50 | 10.99 |
| | 1918 | 48 | 87.08 | 1.56 | 12.07 |
| | 1919 | 69 | 83.16 | 1.95 | 11.58 |
| 31— | 1915 | 1 | 89.47 | 1.57 | 14.91 |
| | 1916 | 1 | 90.14 | 1.07 | 10.85 |
| | 1917 | 7 | 88.35 | 1.44 | 12.36 |
| | 1918 | 40 | 88.41 | 1.47 | 12.68 |
| | 1919 | 82 | 87.60 | 1.74 | 14.03 |
| 773+ | 1915 | 1 | 89.49 | 1.42 | 13.51 |
| | 1916 | 1 | 78.16 | 2.64 | 12.09 |
| | 1917 | 31 | 81.94 | 1.90 | 10.52 |
| | 1918 | 68 | 87.48 | 1.58 | 12.62 |
| | 1919 | .. | .... | ... | .... |
| 531— | 1915 | 1 | 84.27 | 2.01 | 12.78 |
| | 1916 | 1 | 91.53 | .83 | 9.85 |
| | 1917 | 20 | 88.37 | 1.70 | 14.62 |
| | 1918 | 79 | 90.41 | 1.19 | 12.41 |
| | 1919 | .. | .... | ... | .... |
| 900+ | 1915 | 1 | 81.68 | 2.28 | 12.44 |
| | 1916 | 1 | 90.99 | 1.61 | 17.87 |
| | 1917 | 45 | 88.92 | 1.04 | 9.39 |
| | 1918 | .. | .... | ... | .... |
| | 1919 | .. | .... | ... | .... |
| Check+ | 1919 | 67 | 84.86 | 1.86 | 12.29 |
| Series | Years | | | | |
| 270 | 1915-19 | 151 | 85.10 | 1.73 | 11.61 |
| 31— | 1915-19 | 131 | 87.92 | 1.64 | 13.58 |
| 773 | 1915-18 | 101 | 85.71 | 1.69 | 11.83 |
| 531— | 1915-18 | 101 | 89.96 | 1.17 | 11.65 |
| 900 | 1915-17 | 47 | 88.81 | 1.08 | 9.65 |
| Check | 1919 | 67 | 84.86 | 1.86 | 12.29 |
| Average | | | 86.90 | 1.57 | 11 98 |

+=Above average quality; —=below average quality.

15.99 percent and averaged 12.82 percent; and the gradation from "excellent" to "poor" resembles steps in a stairway. In short, "excellent" squashes carry 6 percent less water than "poor" ones, and their dry matter carries about 1.5 percent less protein. The relatively large water content of "poor" squashes is an outstanding characteristic.

## ANALYSES OF COMPOSITE SAMPLES

A more complete analysis was made of composite samples in order to determine the correlation between quality and strain.

The 1917 composite samples constructed on the quality basis were made from groups, 8 specimens classified as excellent, 33 very good, 80 good, 38 fair and 49 poor, while in 1919, there were respectively 38, 51, 44, 85 and 44 specimens in these several groups. In 1917 in passing from "excellent" to "poor" the water contents ranged from 79.6 to 89.5 percent; dry matter from 20.4 to 10.5 percent; ash from 1.1 to 0.7 percent; protein from 2.4 to 1.3 percent; crude fiber from 3.1 to 1.5 percent; crude protein from 2.4 to 1.3 percent; crude fiber from 3.1 to 1.5 percent; nitrogen-free-extract matter from 13.3 to 6.8 percent; and ether extract from 0.6 to 0.3. Similar results were secured in 1919.

On the dry matter basis, it appears that the better qualities as compared with the poorer carry less ash, less crude protein, in one instance more, and in the other less crude fiber, and in one instance more and in the other the same nitrogen-free-extract content.

The composite samples constructed on the "strains" basis covered numbers 270, 773, 531 in 1918 and numbers 270, 31 and checks in 1919. The number of specimens from which samples were taken in each case is indicated in the table. Strains 270 and 773 were "good" and 531 and 31 "poor." As in the quality lot just discussed, the good strains contained less water and more crude protein than the poor strains and in all particulars paralleled the results shown in the upper half of the table. The check lot of 1919 was intermediate in most respects between good (270) and poor (31).

The comparisons of quality and strains on the dry matter basis indicate slightly higher ash and crude protein and ether extract contents, and lower crude fiber and nitrogen-free-extract contents for poor quality. In a word, the two quality strains isolated on the basis of edibility tests were found upon chemical analysis to possess quite important differences in their water and protein contents.

### ANALYSES OF COMPOSITE SAMPLES

| Number of squashes | Quality | Water | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract |
|---|---|---|---|---|---|---|---|---|
| | | | 1917 | | | | | |
| 8 | Excellent | 79.62 | 20.38 | 1.08 | 2.35 | 3.07 | 13.29 | 0.59 |
| 33 | Very good | 83.11 | 16.89 | 0.93 | 1.91 | 2.46 | 11.12 | 0.47 |
| 80 | Good | 87.41 | 12.59 | 0.73 | 1.31 | 1.66 | 8.51 | 0.38 |
| 38 | Fair | 88.62 | 11.38 | 0.67 | 1.37 | 1.43 | 7.59 | 0.32 |
| 49 | Poor | 89.47 | 10.53 | 0.69 | 1.29 | 1.47 | 6.77 | 0.31 |
| | | | 1919 | | | | | |
| 38 | Excellent | 81.34 | 18.66 | 0.97 | 1.97 | 2.34 | 12.85 | 0.53 |
| 51 | Very good | 83.27 | 16.73 | 1.01 | 1.88 | 2.41 | 10.80 | 0.63 |
| 44 | Good | 86.28 | 13.72 | 0.91 | 1.73 | 1.97 | 8.70 | 0.41 |
| 85 | Fair | 88.68 | 11.32 | 0.78 | 1.45 | 2.02 | 6.68 | 0.39 |
| 44 | Poor | 88.40 | 11.60 | 0.85 | 1.55 | 2.05 | 6.75 | 0.40 |
| | | | 1918 | | | | | |
| | Strain | | | | | | | |
| 58 | 270+ | 87.66 | 12.34 | 0.79 | 1.47 | 1.46 | 8.32 | 0.30 |
| 77 | 773+ | 87.79 | 12.21 | 0.86 | 1.50 | 1.80 | 7.62 | 0.43 |
| 95 | 531— | 90.57 | 9.43 | 0.68 | 1.21 | 1.23 | 5.96 | 0.35 |
| 50 | 31— | 88.33 | 11.67 | 0.78 | 1.55 | 2.04 | 6.85 | 0.45 |
| | | | 1919 | | | | | |
| 88 | 270+ | 84.40 | 15.60 | 0.92 | 1.65 | 1.95 | 10.66 | 0.42 |
| 98 | 31— | 87.96 | 12.04 | 0.85 | 1.57 | 2.25 | 6.90 | 0.47 |
| 76 | Check+ | 85.71 | 14.29 | 0.90 | 1.78 | 2.20 | 8.93 | 0.48 |

+ = Above the average; — = below the average.

### DRY MATTER BASIS

| | | | | 100 Parts Dry Matter Contains: | | | |
|---|---|---|---|---|---|---|---|
| Year | Number of squashes | Quality | Crude ash | Crude protein | Crude fiber | Nitrogen free-extract | Ether extract |
| | | | % | % | % | % | % |
| 1917 | 8 | Excellent | 5.29 | 11.51 | 15.05 | 65.27 | 2.88 |
| | 33 | Very good | 5.52 | 11.28 | 14.56 | 65.87 | 2.77 |
| | 80 | Good | 5.82 | 10.40 | 13.15 | 67.58 | 3.05 |
| | 38 | Fair | 5.88 | 12.08 | 12.57 | 66.67 | 2.80 |
| | 49 | Poor | 6.58 | 12.24 | 13.96 | 64.28 | 2.94 |
| 1919 | 38 | Excellent | 5.21 | 10.58 | 12.53 | 68.82 | 2.86 |
| | 51 | Very good | 6.03 | 11.25 | 14.43 | 64.53 | 3.76 |
| | 44 | Good | 6.61 | 12.64 | 14.34 | 63.42 | 2.99 |
| | 85 | Fair | 6.87 | 12.77 | 17.82 | 59.12 | 3.42 |
| | 44 | Poor | 7.30 | 13.38 | 17.67 | 58.18 | 3.47 |
| 1918 | 58 | 279+ | 6.44 | 11.91 | 11.85 | 67.35 | 2.45 |
| | 77 | 773+ | 7.08 | 12.32 | 14.77 | 62.27 | 3.56 |
| | 95 | 531— | 7.16 | 12.78 | 13.05 | 63.25 | 3.76 |
| | 50 | 31— | 6.72 | 13.32 | 17.45 | 58.65 | 3.86 |
| 1919 | 88 | 270+ | 5.87 | 10.57 | 12.49 | 68.38 | 2.69 |
| | 98 | 31— | 7.02 | 13.04 | 18.68 | 57.32 | 3.94 |
| | 76 | Check+ | 6.32 | 12.47 | 15.36 | 62.50 | 3.35 |

+=Above the average quality; —= below average quality.

The relation between quality and different water contents was still further studied. Five quality groups for the several years were placed in classes arbitrarily formed on the basis of their water contents. Specimens exhibiting on the one hand high and on the other low water percentages were segregated for each year and for each quality grade. All specimens above the seasonal average were put in the one, and all below the seasonal average in the other group. In the first table, wherein the grouping is by years, the separations placed 81 "excellent" specimens in the low class and 9 in the high class; "very good," 113 low, 49 high; "good," 112 low, 143 high; "fair," 61 low, 145 high; "poor," 45 low, 117 high, the percentages being respectively 90 and 10; 70 and 30; 44 and 56; 30 and 70; 28 and 72. Seventy-seven percent of the excellent and very good quality squashes were below the average in water content and only 29 percent of those of fair and poor quality. Clearly the water content is an important factor in influencing quality.

GROUPING BY HIGH AND LOW WATER CONTENT

| | Excellent | | Very good | | Good | | Fair | | Poor | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1915 | 11 | 0 | 13 | 8 | 18 | 18 | 16 | 21 | 10 | 21 |
| 1916 | 12 | 6 | 6 | 8 | 8 | 16 | 5 | 10 | 6 | 10 |
| 1917 | 8 | 0 | 28 | 5 | 34 | 45 | 10 | 25 | 11 | 33 |
| 1918 | 14 | 1 | 30 | 13 | 36 | 41 | 20 | 40 | 9 | 31 |
| 1919 | 36 | 2 | 36 | 15 | 16 | 23 | 10 | 49 | 9 | 22 |
| **Total** | 81 | 9 | 113 | 49 | 112 | 143 | 61 | 145 | 45 | 117 |
| **Percentages** | 90 | 10 | 70 | 30 | 44 | 56 | 30 | 70 | 28 | 72 |

Low = below the average; high = above the average.

Similar combinations were made on the basis of protein content, the specimens for each year being listed in the high or low group according as the amount of protein they contained was above or below the seasonal average. This arrangement revealed the fact that 65 percent of the "excellent" and "very good" squashes and 43 percent of the "fair" and "poor" squashes were of low protein content. As is indicated elsewhere a high protein content usually connotes poor quality and vice versa. Undoubtedly variations in moisture, protein and carbohydrate contents influence flavor, palatability and general quality characteristics.

The subjoined table shows the distribution of high and low protein contents among the quality grades ranging from "excellent" to "poor." The distribution is made possible by ascertaining the average protein percentages for each year and assigning the specimens as tested and as analyzed according to their protein content in the grades of quality as exhibited in the table.

The 1915 average protein content in the dry matter was 11.92 percent. There were 9 "excellent" squashes low and 2 that were high in protein as thus determined; and similarly other grades were distributed. The totals for the five years show that 70 "excellent" quality squashes carried less than the average protein content and 20 more; that of the "very good" 95 were below and 67 above; of the "good" 125 below and 130 above; of the "fair" 92 below and 114 above; of the "poor" 68 below and 94 above the average in this respect; the percentage figures being in the order stated: 78 and 22; 59 and 41; 49 and 51; 45 and 55; and 42 and 58, a very consistent lot of comparisons.

GROUPING OF SQUASHES BY HIGH OR LOW PROTEIN CONTENT

Dry Matter Basis

| Year | Average protein | Excellent | | Very good | | Good | | Fair | | Poor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1915 | 11.92 | 9 | 2 | 9 | 12 | 14 | 22 | 19 | 18 | 17 | 14 |
| 1916 | 13.62 | 12 | 6 | 7 | 7 | 14 | 10 | 10 | 5 | 4 | 12 |
| 1917 | 10.43 | 5 | 3 | 20 | 13 | 39 | 40 | 18 | 17 | 23 | 21 |
| 1918 | 12.48 | 12 | 3 | 28 | 15 | 45 | 32 | 28 | 32 | 14 | 26 |
| 1919 | 12.63 | 32 | 6 | 31 | 20 | 13 | 26 | 17 | 42 | 10 | 21 |
| Total | | 70 | 20 | 95 | 67 | 125 | 130 | 92 | 114 | 68 | 94 |
| Percentages | | 78 | 22 | 59 | 41 | 49 | 51 | 45 | 55 | 42 | 58 |

Low = below average; high = above average.

## RELATION OF WATER AND PROTEIN TO QUALITY

In order to find out how protein and water are associated in individual squashes an average was made for each quality-group, each year, of the five squashes that contained the highest and of the five that had the lowest amounts of water. A summary of the results appears below. In nearly every case squash groups carrying the most water also exhibited the highest protein contents, the "fair" group being the only exception.

The averages for all the 250 squashes used in this phase of the study showed that those highest in water content averaged 89.87 percent and contained 12.54 percent protein in dry matter, while those lowest in water content averaged 81.85 percent and contained 11.84 percent of protein in dry matter.

### RELATION OF WATER AND PROTEIN TO QUALITY

Five Year Average of Five Squashes

| Quality | Amount of water | Number of squashes | Original material Water | Original material Protein | Protein in dry matter | Protein in dry matter all squashes |
|---|---|---|---|---|---|---|
| Excellent | Highest | 25 | 85.06 | 1.71 | 11.45 | 11.36 |
| | Lowest | 25 | 79.30 | 2.36 | 11.40 | |
| Very good | Highest | 25 | 89.58 | 1.37 | 13.15 | 11.71 |
| | Lowest | 25 | 80.19 | 2.23 | 11.26 | |
| Good | Highest | 25 | 91.93 | 1.17 | 14.50 | 11.83 |
| | Lowest | 25 | 82.10 | 2.04 | 11.39 | |
| Fair | Highest | 25 | 90.19 | 1.09 | 11.11 | 12.64 |
| | Lowest | 25 | 83.22 | 2.05 | 12.22 | |
| Poor | Highest | 25 | 92.59 | 1.02 | 13.77 | 12.82 |
| | Lowest | 25 | 84.42 | 2.05 | 13.16 | |
| All above grades | Highest | 125 | 89.87 | 1.27 | 12.54 | 12.07 |
| | Lowest | 125 | 81.85 | 2.15 | 11.84 | |

## MATURITY AND COMPOSITION

Some of the squashes tested for quality when cut open proved to be somewhat immature. Their shells were hard but the flesh was partially green. All such specimens were excluded from the test records, but their data were taken and analyses made for comparison with those of full-matured specimens. The table shows that immature squashes contain more water and more crude protein in dry matter than do the mature specimens which, of course, is what might have been expected.

### MATURITY AND COMPOSITION

Average for 1917, 1918, 1919

| Quality | Maturity | Number of squashes | Original material Water | Original material Protein | Protein in dry matter |
|---|---|---|---|---|---|
| | | | % | % | % |
| Good | Mature | 195 | 87.74 | 1.37 | 11.17 |
| | Immature | 6 | 88.04 | 1.50 | 12.54 |
| Fair | Mature | 154 | 88.72 | 1.44 | 12.77 |
| | Immature | 39 | 90.00 | 1.31 | 13.10 |
| Poor | Mature | 115 | 89.18 | 1.37 | 12.66 |
| | Immature | 32 | 91.30 | 1.31 | 15.06 |
| All squashes | Mature | 464 | 88.42 | 1.41 | 12.18 |
| | Immature | 77 | 90.39 | 1.33 | 13.84 |

## HOW SELECT AN "EXCELLENT" SQUASH

As a result of this extensive study carried on for several years, certain suggestions can be offered touching the selection of a Hubbard squash of superior quality. Of course the "proof" of a squash, as of a pudding, "is the eating thereof"; but it is often desirable to know how to choose in advance of eating. Such selection might be desired in order to secure seed for foundation stock for plantings or merely for kitchen use. First of all is the matter of ripeness and full maturity as indicated by good size and hardness of the shell. It was rare in our experience to find an excellent specimen extreme in size, either too large or too small. "Excellent" squashes rarely weighed less than 6, or more than 12 pounds, the average weight in the 1918 crop being 9.4 pounds. Thickness of shell seemed also to be associated with superior quality. "Excellent" squashes had very thick shells, in fact much thicker than those of any other grade, for they averaged 4.8 mm. in contrast to 1.4 mm. for poor ones. The color of the shell and flesh is also of diagnostic value. Typical Hubbards are dark green with dirty white streaks at harvest. During storage the color becomes a dirty brown and towards spring may become yellowish bronze. The flesh should be dark orange, devoid of green, and there should be a clear demarcation between shell and flesh. However, some very fine specimens show a pink flesh shading to old gold. The thickness of flesh does not seem to be correlated with either good or poor quality. A little attention to the character of the flesh will assist one in avoiding stringy specimens. It was a matter of common observation that a squash with an abundant placenta about the seed had also an abundance of these fibers within the flesh, thus contributing to poor quality.

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SEPTEMBER, 1921 BULLETIN 223

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University of Vermont and State Agricultural College

# Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

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# COMMERCIAL FERTILIZERS
# COMMERCIAL FEEDING STUFFS
# AGRICULTURAL SEED

BURLINGTON
FREE PRESS PRINTING COMPANY
1921

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Director's office, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place. University farm and buildings are on the Williston road, adjoining the University Campus on the east.

# BULLETIN 223: COMMERCIAL FERTILIZERS, COMMERCIAL FEEDING STUFFS, AGRICULTURAL SEED

BY J. L. HILLS, C. H. JONES, G. F. ANDERSON, ANNA S. LUTMAN

The results of the police work performed during 1921 by the Station in accordance with state laws is set forth in condensed form in this bulletin. The Station regrets its inability to furnish the full information which has been vouchsafed prior to 1919.

It may be said in brief:

*Fertilizer Control.* That the fertilizers sold in 1921, as a whole, were quite as good as they were represented to be.—Pages 3-12.

*Feeding Stuffs Inspection.* That the results were normal, only 3½ percent of the brands being deficient and only 2 percent seriously so.—Pages 12-19.

*Agricultural Seed Inspection.* That one lot in 10 was not guaranteed; that one in 10 was deficient and one in 50 seriously deficient in respect to the maintenance of the purity guaranty.—Pages 19-30.

## FERTILIZER CONTROL

The sampling agents of the Station visited no less than 108 Vermont cities, towns and villages in the spring and early summer of 1921 and drew 521 samples from dealers' stock representing 137 of the 153 brands of commercial fertilizers licensed for sale by the following companies:

| Licensees | Licensed brands | Brands sampled | Brands not found |
|---|---|---|---|
| American Agricultural Chemical Co. | 38 | 36 | 2 |
| Armour Fertilizer Works | 8 | 3 | 5 |
| Atlantic Packing Co. | 4 | 4 | .. |
| Bowker Fertilizer Co. | 7 | 7 | .. |
| Burlington Rendering Co. | 5 | 5 | .. |
| Coe-Mortimer Co. | 5 | 5 | .. |
| Earp-Thomas Cultures Co. | 1 | 1 | .. |
| Eastern States Farmers' Exchange | 7 | 7 | .. |
| Essex Fertilizer Co. | 10 | 8 | 2 |
| International Agricultural Corporation, Buffalo Fertilizer Works | 8 | 8 | .. |
| Listers' Agricultural Chemical Works | 8 | 8 | .. |
| Lowell Fertilizer Co. | 10 | 10 | .. |
| New England Fertilizer Co. | 6 | 6 | .. |
| Nitrate Agencies Co. | 9 | 5 | 4 |
| C. S. Page | 2 | 2 | .. |
| Parmenter & Polsey Fertilizer Co. | 7 | 6 | 1 |
| Reading Bone Fertilizer Co. | 7 | 6 | 1 |
| Rogers & Hubbard Co. | 7 | 6 | 1 |
| Sanderson Fertilizer and Chemical Co. | 3 | 3 | .. |
| Virginia-Carolina Chemical Co. | 1 | 1 | .. |
|  | 153 | 137 | 16 |

No samples of the following named brands were secured; no sales being made in several instances.

**American Agricultural Chemical Company's Bradley's Valley Tobacco Fertilizer**
**American Agricultural Chemical Company's Quinnipiac Phosphate**
**Armour Fertilizer Company's Big Crop Five-Eight-Five**
**Armour Fertilizer Company's Big Crop Four-Ten-Zero**
**Armour Fertilizer Company's Big Crop Potato and Onion Four-Eight-Four**
**Armour Fertilizer Company's Big Crop Three-Eight-Four**
**Armour Fertilizer Company's Big Crop Zero-Ten-Five**
**Essex Fertilizer Company's Four-Eight-Six**
**Essex Fertilizer Company's Five-Eight**
**Nitrate Agencies Company's Five-Eight-Four**
**Nitrate Agencies Company's Nitropo**
**Nitrate Agencies Company's Three-Ten-Zero**
**Nitrate Agencies Company's Two-Ten-Zero**
**Parmenter & Polsey Company's Four-Eight-Four**
**Reading Bone Fertilizer Company's High Grade Truck Food**
**Rogers & Hubbard Company's "Bone Base" Fertilizer for Seeding Down**

The following condensed statements set forth the essential facts as to the maintenance of guaranties. The order of statement is alphabetical by names of manufacturers.

The first four figures in the table, reading horizontally following the brand name, indicate what the manufacturers' promises were, expressed in percentage terms; and the word following, usually "Yes", less often "No", tells in this laconic, straightforward fashion whether or not the promises have been kept. The remaining words and figures, other than the last two, show the quality of the nitrogen purveyed by the manufacturer. By the use of the words "Passed" or "Not Passed" the character of the organic nitrogen is set forth. The former word is used whenever the analysis indicated a good or passable grade; the latter words when it did not. The next two statements in terms of decimals indicate the proportions of the total nitrogen present in water-soluble and water-insoluble forms. The former includes nitrate nitrogen, ammoniacal nitrogen and such organic nitrogen as is water-soluble; the latter such organic nitrogen as is not soluble in water, more or less of which—more in some cases, less in others—is available to plant growth. The last figure, reading horizontally, indicates in terms of a decimal what proportion of the total phosphoric acid is furnished in available form. The last column shows by the presence of the letter C or S as the case may be whether the potash, if present, was present as muriate or chlorid (C) or as sulphate (S). In case both were present, the letters CS or SC are used, the one first given indicating predominance.

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Quality organic nitrogen? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | | Water-soluble | Water-insoluble | | |
| **American Agricultural Chemical Company, 92 State St., Boston, Mass.** | | | | | | | | | | |
| Bone-Phosphate and Potash.... | ... | 13 | 12 | 2 | Yes | Passed | .. | .. | 1.0 | C |
| Complete Potato Mixture...... | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Four-Eight-Six Fertilizer....... | 3.29 | 9 | 8 | 6 | No | Passed | .8 | .2 | .9 | C |
| Grass and Lawn Top Dressing.. | 4.94 | 7 | 6 | 4 | Yes | Passed | .8 | .2 | .8 | C |
| Grass and Oats Fertilizer...... | ... | 13 | 12 | 2 | Yes | Passed | .. | .. | 1.0 | C |
| Monarch Potato Manure....... | 3.29 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .8 | C |
| Universal Phosphate .......... | 0.82 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | 1.0 | C |
| Vegetable and Vine Fertilizer.. | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| *(Bradley Fertilizer Company Brands)* | | | | | | | | | | |
| Complete Manure for Top Dressing Grass and Grain ........ | 4.94 | 7 | 6 | 4 | Yes | Passed | .9 | .1 | .9 | C |
| Complete Tobacco Manure .... | 4.11 | 5 | 4 | 5 | Yes | Passed | .4 | .6 | .9 | SC |
| Corn Phosphate .............. | 1.65 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Eclipse Phosphate ............ | 0.82 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | CS |
| Northland Potato Grower ..... | 3.29 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Potato Fertilizer ............. | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .8 | SC |
| Potato Manure ................ | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | CS |
| Reliable 6% Potash Fertilizer. | 3.29 | 9 | 8 | 6 | Yes | Passed | .8 | .2 | .9 | C |
| XL Superphosphate of Lime... | 2.47 | 10 | 9 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| *(Crocker Fertilizer & Chemical Company Brands)* | | | | | | | | | | |
| Ammoniated Corn Phos., 1920.. | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | 1.0 | C |
| New Rival Ammoniated Superphosphate, 1920 ............ | 0.82 | 9 | 8 | 2 | Yes | Passed | .5 | .5 | .9 | C |
| Potato, Hop and Tobacco Fertilizer, 1920 ................ | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| *(L. B. Darling Company Brands)* | | | | | | | | | | |
| Farm Favorite ............... | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Potato Fertilizer ............. | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| *(Great Eastern Fertilizer Company Brands)* | | | | | | | | | | |
| General, 1921 ................ | 0.82 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Northern Corn Special, 1920.... | 1.65 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Potato Manure, 1920 .......... | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | C |
| *(Pacific Guana Company Brands)* | | | | | | | | | | |
| Pacific Potato Special ........ | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | 1.0 | C |
| Soluble Pacific Guano........ | 1.65 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| *(Quinnipiac Company Brands)* | | | | | | | | | | |
| Corn Manure ................ | 1.65 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | 1.0 | C |
| Potato Manure ............... | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Potato Phosphate ............. | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | C |
| *(Read Fertilizer Company Brands)* | | | | | | | | | | |
| Farmers' Friend Superphosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Practical Potato Special Fert... | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | C |

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| Brand | Guaranties | | | | Guaranty met? | Quality organic nitrogen? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | | Water-soluble | Water-insoluble | | |
| *(Williams & Clark Fertilizer Company Brands)* | | | | | | | | | | |
| Americus Ammoniated Bone Superphosphate | 2.47 | 10 | 9 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Americus Corn Phosphate | 1.65 | 9 | 9 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Americus Potato Manure | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | C |
| Potato Phosphate | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| **Armour Fertilizer Works, 1501-1514 Munsey Building, Baltimore, Md.** | | | | | | | | | | |
| Big Crop 2/10/6 | 1.65 | 10.5 | 10 | 6 | Yes | Passed | .6 | .4 | .9 | C |
| Corn Grower 2/8/2 | 1.65 | 8.5 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| General Crop Fertilizer 1/7/1 | 0.82 | 7.5 | 7 | 1 | Yes | Passed | .6 | .4 | .9 | C |
| **Atlantic Packing Company, North Ave., Burlington, Vt.** | | | | | | | | | | |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | Passed | .6 | .4 | .9 | C |
| Three-Eight-Four | 2.47 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Two-Eight-Three | 1.65 | 9 | 9 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Two | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| **Bowker Fertilizer Company, 43 Chatham St., Boston, Mass.** | | | | | | | | | | |
| All Round Fertilizer | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Corn, Grain and Grass Phos. | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Hill and Drill Phosphate | 2.47 | 10 | 9 | 2 | Yes | Passed | .8 | .2 | .8 | SC |
| Potato and Vegetable Phosphate | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | SC |
| Stockbridge Early Crop Manure | 4.11 | 9 | 8 | 7 | Yes | Passed | .8 | .2 | .9 | C |
| Stockbridge Market Garden Man. | 3.29 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Sure Crop Phosphate | 0.82 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| **Burlington Rendering Company, North Ave., Burlington, Vt.** | | | | | | | | | | |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| One-Ten-One | 0.82 | 11 | 10 | 1 | Yes | Passed | .6 | .4 | .9 | C |
| Three-Eight-Four | 2.47 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Two-Eight-Three | 1.65 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Two | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .8 | C |
| **Coe-Mortimer Company, 51 Chambers St., New York, N. Y.** | | | | | | | | | | |
| Celebrated Special Potato Fertilizer Revised | 3.29 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Columbian Corn and Potato Fert. | 1.65 | 9 | 8 | 3 | Yes | Passed | .8 | .2 | .9 | C |
| Corn King | 2.47 | 10 | 9 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| New Englander Special | 0.82 | 9 | 8 | 2 | Yes | Passed | .8 | .2 | 1.0 | C |
| Special Grass Top Dressing | 4.92 | 7 | 6 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| **Earp-Thomas Cultures Company, New York, N. Y.** | | | | | | | | | | |
| Stim-U-Plant Tablets | 11 | .. | 12 | 15 | Yes | Passed | 1.0 | 0 | 1.0 | CS |
| **Eastern States Farmers' Exchange, 292 Worthington St., Springfield, Mass.** | | | | | | | | | | |
| Five-Eight-Five | 4.11 | 9 | 8 | 5 | No | Passed | .6 | .4 | .9 | CS |
| Five-Four-Five | 4.1 | 5 | 4 | 5 | Yes | Passed | .4 | .6 | .9 | SC |
| Four-Eight-Four | 3.28 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Four-Eight-Seven | 3.28 | 9 | 8 | 7 | No | Passed | .8 | .2 | .9 | C |
| Four-Ten | 3.28 | 11 | 10 | .. | Yes | Passed | .8 | .2 | .9 | .. |
| Three-Eight-Four | 2.45 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .9 | C |

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Quality organic nitrogen? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | | Water-soluble | Water-insoluble | | |
| **Essex Fertilizer Company, 39 North Market St., Boston, Mass.** | | | | | | | | | | |
| Bone Fertilizer 2/10/0 | 1.64 | 11 | 10 | .. | No | Passed | .6 | .4 | .9 | C |
| Fish Fertilizer 3/8/3 | 2.46 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |
| Four-Eight-Four | 3.28 | 9 | 8 | 4 | No | Passed | .7 | .3 | .8 | C |
| Market Garden 3/8/4 | 2.46 | 9 | 8 | 4 | No | Passed | .7 | .3 | .9 | C |
| One-Ten-One | 0.82 | 11 | 10 | 1 | Yes | Not passed | .5 | .5 | .9 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Three for all Crops | 1.64 | 9 | 8 | 3 | No | Passed | .5 | .5 | .9 | C |
| Two-Eight-Six | 1.65 | 9 | 8 | 6 | Yes | Passed | .6 | .4 | .9 | C |
| **International Agricultural Corporation** | | | | | | | | | | |
| **Buffalo Fertilizer Works, 812 Marine Bank Building, Buffalo, N. Y.** | | | | | | | | | | |
| Buffalo Economy | 1.65 | 9 | 8 | 2 | Yes | Passed | .7 | .3 | .8 | C |
| Buffalo High Grade Manure | 3.29 | 9 | 8 | 6 | Yes | Passed | .5 | .5 | .9 | C |
| Buffalo Farmers' Choice | 0.82 | 11 | 10 | 2 | Yes | Passed | .8 | .2 | .9 | C |
| Buffalo Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | Passed | .5 | .5 | .8 | C |
| Buffalo New England Special | 1.65 | 11 | 10 | 4 | Yes | Passed | .6 | .4 | .9 | CS |
| Buffalo Phosphate and Potash | ... | 11 | 10 | 4 | Yes | Passed | .. | .. | .9 | CS |
| Buffalo Top Dresser and Starter | 5.76 | 7 | 6 | .. | Yes | Passed | .6 | .4 | .7 | .. |
| Buffalo Vegetable and Potato | 2.47 | 9 | 8 | 4 | Yes | Passed | .6 | .4 | .9 | C |
| **American Agricultural Chemical Company** | | | | | | | | | | |
| **Listers' Agricultural Chemical Works, Lister Ave., Newark, N. J.** | | | | | | | | | | |
| Corn and Potato Fertilizer | 1.65 | 9 | 8 | 3 | No | Passed | .5 | .5 | .8 | C |
| Eastern Pride Fertilizer | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .8 | C |
| Fish and Potash Fertilizer | 2.47 | 11 | 10 | 3 | Yes | Passed | .7 | .3 | .8 | C |
| Four-Eight-Four Fertilizer | 3.29 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .7 | C |
| Grain and Grass Fert. Revised | ... | 13 | 12 | 2 | Yes | Passed | .. | .. | .9 | C |
| Jersey Potato Fertilizer | 3.29 | 9 | 8 | 6 | Yes | Passed | .8 | .2 | .8 | C |
| Squirrel Brand Fertilizer | 0.82 | 9 | 8 | 2 | No | Passed | .7 | .3 | .9 | C |
| Success Fertilizer | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .7 | C |
| **Lowell Fertilizer Company, 40 North Market St., Boston, Mass.** | | | | | | | | | | |
| Animal Brand 3/8/4 | 2.46 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Bone Fertilizer 2/8/2 | 1.64 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Dissolved Bone Fertilizer 2/10/0 | 1.64 | 11 | 10 | .. | Yes | Passed | .5 | .5 | .9 | .. |
| Empress 1/10/1 | 0.82 | 11 | 10 | 1 | Yes | Not passed | .6 | .4 | .8 | C |
| Five-Eight-Four | 4.11 | 9 | 8 | 4 | No | Passed | .7 | .3 | .9 | C |
| Four-Eight-Four | 3.28 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Four-Eight-Seven | 3.28 | 9 | 8 | 7 | Yes | Passed | .7 | .3 | .9 | C |
| Four-Eight-Six | 3.28 | 9 | 8 | 6 | Yes | Passed | .7 | .3 | .9 | C |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .5 | .5 | .9 | C |
| Two-Eight-Six | 1.64 | 9 | 8 | 6 | Yes | Passed | .5 | .5 | .9 | C |
| **New England Fertilizer Company, 40A North Market St., Boston, Mass.** | | | | | | | | | | |
| Corn Phosphate 2/8/2 | 1.64 | 9 | 8 | 2 | No | Passed | .4 | .6 | .9 | C |
| Four-Eight-Four | 3.28 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | C |
| Standard Phosphate 1/10/1 | 0.82 | 11 | 10 | 1 | Yes | Not passed | .5 | .5 | .8 | C |
| Superphosphate 3/8/4 | 2.46 | 9 | 8 | 4 | No | Passed | .7 | .3 | .9 | C |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Six | 1.64 | 9 | 8 | 6 | Yes | Passed | .5 | .5 | .9 | C |

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties |  |  |  | Guaranty met? | Quality organic nitrogen? | Nitrogen |  | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash |  |  | Water-soluble | Water-insoluble |  |  |
| **Nitrate Agencies Company, 85 Water St., New York, N. Y.** |  |  |  |  |  |  |  |  |  |  |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .9 | CS |
| Four-Eight-Seven | 3.29 | 9 | 8 | 7 | Yes | Passed | .7 | .3 | .9 | SC |
| Four-Ten | 3.29 | 11 | 10 | .. | Yes | Passed | .5 | .5 | .9 | .. |
| Three-Eight-Four | 2.46 | 9 | 8 | 4 | Yes | Passed | .7 | .3 | .8 | CS |
| Two-Eight-Two | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| **Carroll S. Page, Hyde Park, Vt.** |  |  |  |  |  |  |  |  |  |  |
| No Filler Fertilizer | 2.47 | 15 | 10 | .. | Yes | Passed | .5 | .5 | .7 | .. |
| No Filler Fert., Potash Brand | 3.29 | 10 | 9 | 4 | Yes | Passed | .6 | .4 | .7 | C |
| **Parmenter & Polsey Fertilizer Company, 41 North Market St., Boston, Mass.** |  |  |  |  |  |  |  |  |  |  |
| One-Ten-One | 0.82 | 11 | 10 | 1 | Yes | Not passed | .6 | .4 | .9 | C |
| Plymouth Rock Brand 3/8/4 | 2.46 | 9 | 8 | 4 | No | Passed | .7 | .3 | .9 | C |
| Three-Eight-Three | 2.46 | 9 | 8 | 3 | No | Passed | .6 | .4 | .9 | C |
| Two-Eight-Three | 1.64 | 9 | 8 | 3 | Yes | Passed | .5 | .5 | .9 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | C |
| Two-Eight-Six | 1.64 | 9 | 8 | 6 | Yes | Passed | .6 | .4 | .9 | C |
| **Reading Bone Fertilizer Company, Reading, Pa.** |  |  |  |  |  |  |  |  |  |  |
| Dissolved Animal Matter | 0.82 | 11 | 10 | .. | Yes | Passed | .8 | .2 | .9 | .. |
| Economy Brand | ... | 11 | 10 | 4 | Yes | Passed | .. | .. | .9 | C |
| Farmers' Tankage and Potash | 0.82 | 11 | 10 | 2 | Yes | Passed | .7 | .3 | .9 | C |
| Reading All Crop Special | 1.64 | 11 | 10 | .. | Yes | Passed | .8 | .2 | .9 | .. |
| Reading One-Eight-Five | 0.82 | 9 | 8 | 5 | Yes | Passed | .8 | .2 | .9 | C |
| Reading Special Potato and Tobacco Manure | 0.82 | 13 | 12 | .. | Yes | Passed | .7 | .3 | .9 | .. |
| **Rogers & Hubbard Company, Middletown, Conn.** |  |  |  |  |  |  |  |  |  |  |
| All Soils—All Crops Phosphate | 3.29 | 9 | 8 | 4 | Yes | Passed | .9 | .1 | .8 | C |
| "Bone Base" Oats and Top Dressing | 8.22 | 8 | 3 | 4 | Yes | Passed | .8 | .2 | .4 | CS |
| "Bone Base" Sol. Corn and General Crops Manure | 2.46 | 10 | 8 | 4 | No | Passed | .8 | .2 | .8 | C |
| "Bone Base" Sol. Potato Manure | 4.11 | 10 | 8 | 6 | No | Passed | .8 | .2 | .8 | SC |
| Complete Phosphate | 0.82 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .7 | C |
| Potato Phosphate | 1.64 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .8 | C |
| **Sanderson Fertilizer & Chemical Company, New Haven, Conn.** |  |  |  |  |  |  |  |  |  |  |
| Atlantic Coast Bone, Fish and Potash | 1.65 | 9 | 8 | 3 | Yes | Passed | .5 | .5 | .8 | C |
| Corn Superphosphate | 1.65 | 9 | 8 | 2 | Yes | Passed | .6 | .4 | .9 | CS |
| Potato Manure | 2.47 | 9 | 8 | 4 | Yes | Passed | .8 | .2 | .9 | C |
| **Virginia-Carolina Chemical Company, New York, N. Y.** |  |  |  |  |  |  |  |  |  |  |
| Owl Brand | 1.65 | 9 | 8 | 3 | Yes | Passed | .7 | .3 | .9 | C |

The following divergencies from guaranties seem to call for special notice:

### AMERICAN AGRICULTURAL CHEMICAL COMPANY

*4/8/6 Fertilizer.* Nitrogen 0.1% and potash 0.3 % short of guaranty; available phosphoric acid 0.1% over guaranty. Shortage in plant food 2%.

### ARMOUR FERTILIZER COMPANY

*Corn and Grain.* Available phosphoric acid 0.3% short of guaranty, but nitrogen and potash, respectively, 0.2% and 0.5% above guaranty. No shortage in total plant food.

### EARP-THOMAS CULTURES COMPANY

*Stim-U-Plant Tablets.* Available phosphoric acid 0.6% short of guaranty, but nitrogen and potash, respectively, 0.5% and 0.5% above guaranty. No shortage in total plant food.

### EASTERN STATES FARMERS' EXCHANGE

*4/8/7.* Nitrogen 0.4% short of guaranty, but potash 0.8% above guaranty. No shortage in total plant food.

*5/8/5.* Nitrogen 0.6% short of guaranty, but potash 0.5% above guaranty. No shortage in total plant food.

### ESSEX FERTILIZER COMPANY

*Market Garden 3/8/5.* Nitrogen 0.5% short of guaranty; available phosphoric acid and potash 0.7% above guaranty. No shortage in total plant food.

*2/8/3 for All Crops.* Available phosphoric acid 0.5% short of guaranty; nitrogen 0.15% short of guaranty; potash 0.4% above guaranty. Shortage in total plant food 2%.

*Bone Fertilizer 2/10/0.* Available phosphoric acid 0.5% short of guaranty; nitrogen barely meets guaranty. Shortage in total plant food 4%.

*4/8/4.* Nitrogen 0.3% short of guaranty; available phosphoric acid barely meets guaranty; potash 0.3% over guaranty. No shortage in total plant food.

### LISTERS' AGRICULTURAL CHEMICAL WORKS

*Corn and Potato Fertilizer.* Available phosphoric acid 0.5% low of guaranty, but potash 0.3% over guaranty; nitrogen barely meets guaranty. Shortage in total plant food 1%.

*4/8/4.* Available phosphoric acid 0.4% short of guaranty, but potash and nitrogen, respectively, 0.5% and 01% high of guaranty. No shortage in total plant food.

*Squirrel Brand.* Potash 0.3% short of guaranty; nitrogen and available phosphoric acid just meets guaranty. Shortage in total plant food 3%.

### LOWELL FERTILIZER COMPANY

*5/8/4.* Nitrogen 0.4% low, but available phosphoric acid 0.4% high and potash 2.2% high of guaranty. Probably a shipment of 4/8/6 in place of 5/8/4. No shortage in total plant food.

*Animal Brand 3/8/4.* Nitrogen 0.2% low of guaranty, but available phosphoric acid 0.6% high of guaranty. No shortage in total plant food.

*Empress 1/10/1.* Available phosphoric acid 0.3% low, but potash 0.5% high of guaranty. No shortage in total plant food.

*2/8/6.* Available phosphoric acid 0.4% short of guaranty, but nitrogen 0.4% high. No shortage in total plant food.

*Dissolved Bone.* Available phosphoric acid 0.4% short of guaranty, but nitrogen 0.3% high of guaranty. No shortage in total plant food.

### NEW ENGLAND FERTILIZER COMPANY

*Corn Phosphate.* Nitrogen and available phosphoric acid, respectively, 0.3% and 0.4% short of guaranty; potash barely meets guaranty. Shortage in plant food 6%.

*Superphosphate.* Nitrogen 0.4% short of guaranty; available phosphoric acid and potash barely meets guaranties. Shortage in plant food 4%.

### PARMENTER & POLSEY FERTILIZER COMPANY

*Plymouth Rock.* Nitrogen 0.3% short of guaranty, but available phosphoric acid 0.4% above guaranty. No shortage in total plant food.

*3/8/3.* Nitrogen 0.6% short of guaranty, but available phosphoric acid and potash, respectively, 0.4% and 0.9% above guaranty. No shortage in total plant food.

### ROGERS & HUBBARD COMPANY

*"Bone Base" Soluble Corn and General Crops Manure.* Nitrogen 0.1% and available phosphoric acid 0.6% short of guaranty; potash 0.4% above guaranty. Shortage in plant food 2%.

*"Bone Base" Soluble Potato Manure.* Available phosphoric acid 0.9% short of guaranty; nitrogen 0.2% and potash 1% above guaranty. No shortage in total plant food.

## DISCUSSION OF THE RESULTS OF INSPECTION

*Quantity of plant food.* Fertilizers sold in Vermont in the spring of 1921—if one may judge by the results of inspection—as a whole were up to the usual grade. There were 399 guaranties made, 32 of which, or one in 12, were not maintained. However, of these 33 deficiencies only four, or one in 100, of the entire number were in excess of 0.5%. In 22 of the 29 brands there was no shortage of total plant food, that is to say, a deficiency in one form, e. g., nitrogen, was made but by excess over guaranty of another form, e. g., potash. In the other seven brands the deficiencies in no case were greater than 6% and in five of the seven cases were 3 or less percent. The manufacturers, as usual, and very properly, furnished very little more plant food than they promised to supply. The average fertilizer sold in Vermont in 1920 was guarantied to contain approximately 2¼% nitrogen, 9¼% total and 8¼% available phosphoric acid, and 3¼% potash; and it averaged to contain very little more than these figures.

*Quality of plant food.* The information heretofore vouchsafed as to the nitrate and ammoniacal nitrogen contents of the several brands can not be furnished this year. However, the availability of the organic nitrogen was determined as usual and four brands were found to contain what seemed to be undue amounts of unavailable organic nitrogen, namely: Essex Fertilizer Company's One-Ten-One; Lowell Fertilizer Company's Empress Brand One-Ten-One; New England Fertilizer Company's Standard Phosphate One-Ten-One; and the Parmenter & Polsey Company's One-Ten-One.

The proportions of phosphoric acid furnished in available forms by the several companies vary about as usual. It is gratifying to note the reappearance of potash in considerable quantities.

As was pointed out last year there are really only about 25 different grades sold and 70 percent of the brands readily list in seven grades, as follows: 1-8 to 10-2; 2-8-2; 2-8-3; 3-8-4; 4-8-4; 4-8-6 or 7; 5-4/8-4/5. It is interesting to note the change in the character of the usage in 1920 and 1921. Essentially the same proportion of licenses of non-nitrogenous and of 1, 2, 3 and 4 percent potash goods were noted each year; but the non-potassic goods dropped from 15 to 9 percent of the total number and the high potash and high nitrogen goods increased from 9 to 18 percent of the entire number.

## FEEDING STUFFS INSPECTION

The sampling agents of the Station visited more than 50 cities, towns and villages in Vermont in the spring of 1920, and drew 643 samples from dealers' stocks, representing almost 300 brands of goods which either are subject to or exempt from the necessity of guaranty. The samples have been examined chemically for protein only.

The law seems fairly well observed at present. Unguaranteed goods are infrequent and overguaranties are not as common as once they were; but overstatements in advertising occur.

The following condensed statements set forth the facts as to protein guaranty maintenance as determined in the present inspection. Within groups, the order of statement is alphabetical by names of manufacturers or jobbers. Manufacturers' or jobbers' names and addresses are printed in SMALL CAPITALS, brand names in *italics,* guaranties in figures in parenthesis following the brand name. The deficiency in protein contents, if any, is stated following the guaranty in *italics.*

### COTTONSEED MEALS

#### PROTEIN GUARANTIES FULFILLED

American Cotton Oil Co., Memphis, Tenn., *Aco* (41.18); *Surety* (36). Ashcroft-Wilkinson Co., Memphis, Tenn., *Helmet* (41); *Paramount* (36). F. W. Brodé Co., Memphis, Tenn., *Jay* (36); *Owl 36* (36). Buckeye Cotton Oil Co., Cincinnati, O., *Buckeye* (36). Cold Press Mill, Memphis, Tenn., *Ward's Pride* (41). Cottonseed Products Co., Louisville, Ky., *Prime* (41). S. P. Davis, Little Rock, Ark., *Good Luck* (41). Humphreys-Godwin Co., Memphis, Tenn., *Bull* (43); *Danish* (36); *Dixie* (41); *Forfat* (38.55). L. B. Lovitt & Co., Memphis, Tenn., *Thirty-six* (36). Park & Pollard Co., Boston, Mass., *Upland* (36). J. E. Soper Co., Boston, Mass., *Puritan* (36). Speir & McKay, Atlanta, Ga., *Good* (36. A. C. Westervelt & Co., Memphis, Tenn., *Planet* (43).

#### PROTEIN GUARANTIES NOT FULFILLED

F. W. Brodé Co., Memphis, Tenn., *Owl* (guaranty 41, analysis 38.4). Buckeye Cotton Oil Co., Cincinnati, O., *Good* (guaranty 36, analysis 31.1). Cottonseed Products Co., Louisville, Ky., ———— (guaranty 36, analysis 33.6). Union Seed & Fertilizer Co., Memphis, Tenn., *Yellow Tag* (guaranty 41, analysis 37.5).

## LINSEED MEAL

### PROTEIN GUARANTIES FULFILLED

American Linseed Co., Buffalo, N. Y., *Old Process Oil Meal* (32), (32). Archer-Daniels Linseed Co., Buffalo, N. Y., *Old Process Ground Oil Cake* (31). Midland Linseed Products Co., Minneapolis, Minn., *Pure Old Process Ground Linseed Cake* (30), (30), (32). Spencer Kellogg & Sons, Inc., Undercliff, N. J., Buffalo, N. Y., *Pure Old Process Oil Meal* (31), (33).

### PROTEIN GUARANTIES NOT FULFILLED

Kelloggs & Miller, Amsterdam, N. Y., *Pure Oil Process Oil Meal* (guaranty 31, analysis 30.4). Mann Bros. Co., Buffalo, N. Y., *Pure Old Process Oil Meal* (guaranty 31, analyses 29.9). Midland Linseed Products Co., Minneapolis, Minn., ———— (guaranty 32, analysis 30.8; guaranty 36, analysis 30.4).

## GLUTEN FEEDS

### PROTEIN GUARANTIES FULFILLED

American Maize Products Co., New York, N. Y., *Cream of Corn* (23). Clinton Corn Syrup Refining Co., Clinton, Iowa, *Clinton* (23), (†). Corn Products Refining Co., New York, N. Y., *Buffalo* (23). A. E. Staley Manufacturing Co., Decatur, Ill., *Staley's* (23), (23), (23), (23).

## DISTILLERS, ETC., BYPRODUCTS

### PROTEIN GUARANTIES FULFILLED

Fleischmann Co., Peekskill, N. Y., *Fleischmann's Dried Malt Grains* (22). Pennsylvania Grain & Feed Co., ————, *Peerless Brewers' Dried Grains* (20). United States Food Products Corporation, Peoria, Ill., *Farmer Jones Corn Distillers' Grains* (30).

## PEANUT FEEDS

### PROTEIN GUARANTIES FULFILLED

Humphrey-Godwin Co., Memphis, Tenn., *Liberty* (30). Wills Point Cotton Oil Co., ————, *Ground Whole* (30).

## WHEAT OFFALS—WHEAT BRAN

### PROTEIN GUARANTIES FULFILLED

Aunt Jemima Mills Co., St. Joseph, Mo., *Bran and Screenings not over 6% mill run* (14.5). E. W. Bailey & Co., Montpelier, Vt., *Pennant* (14.5). Big Diamond Mills Co., ————, *Big Diamond** (13). Commander Milling Co., Minneapolis, Minn., *Durum* (11.5); *Durum* (12). Commercial Milling Co., Detroit, Mich., ———— (14.5). Duluth-Superior Milling Co., Duluth, Minn., *Duluth Imperial** (15). Empire Milling Co., Minneapolis, Minn., *Empire** (13). Federal Milling Co., Lockport, N. Y., *Lucky** (12). Ipswich Milling Co., Ipswich, So. Dak., ———— (15). J. C. Lysle Milling Co., Leavenworth, Kans., *Bran and Screenings not over 8%* (15). H. D. Lee Flour Mills Co., Salina, Kans., *Bran and Screenings not to exceed 8%* (14.5). Maple Leaf Milling Co., Ltd., Toronto, Can., ———— (14); ———— (15.5). Northwestern Consolidated Milling Co., Minneapolis, Minn., ———— (13). Ogilvie Flour Mills Co., Winnipeg, Man., ————* (13). Pillsbury Flour Mills Co., Minneapolis, Minn., _Pillsbury's_* (13). Quaker Oats Co., Chicago, Ill., _Bellcorn_* (15.3). Quaker City Flour Milling Co., Philadelphia, Pa., ———— (10); ———— (13). Russell-Miller Milling Co., Minneapolis, Minn., ———— (13); ———— (12); _Bran and Screenings not exceeding 8%_ (12). F. W. Stock & Sons, Hillsdale, Mich., ————* (14). Thompson Milling Co., Lockport, N. Y., _Angelus_* (11). Washburn-Crosby Co., Minneapolis, Minn., ————* (13); ————* (13). Western Canada Flour Mills Co., Ltd., Winnipeg, Man., _Pioneer_* (14.5); ————* (14.5); ————* (14.5); ————* (14.5); _Western Canada_ (no guaranty, analysis 18.6). Wichita Flour Mills Co., Wichita, Kans., _Bran and Screenings not over 5%_ (14.5). Yerxa, Andrews & Thurston, Minneapolis, Minn., _Durum_ (14).

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*With ground screenings not exceeding mill run.

†Shipped in bulk. Local dealers knew nothing about the guaranty and had bagged the goods in divers and sundry bags with all sorts of brand markings, thus defeating the intent of the law. The price was considerably lower than was asked for bagged goods, but the crude protein content was barely nine-tenths as great. However, it was equivalent to the usual guaranty of this brand.

## WHEAT OFFALS—WHEAT MIDDLINGS

### PROTEIN GUARANTIES FULFILLED

Barber Milling Co., Minneapolis, Minn., ————* (16). Bay State Milling Co., Winona, Minn., _Bay State_* (15.9). Bill, Bell & Co., Ogdensburg, N. Y., _Flour_* (13.75). Duluth-Superior Milling Co., Duluth, Minn., _Standard S._* (16). Empire Milling Co., Minneapolis, Minn., _Standard_* (15). Federal Milling Co., Lockport, N. Y., _Dairymaid_* (13). International Milling Co., Minneapolis, Minn., _Black Hawk Standard_* (14). Listman Milling Co., ————, _Elmco Standard_* (17.3). Maple Leaf Milling Co., Ltd., Toronto, Ont., _Rex_* (10). Ogilvie Flour Mills Co., Winnipeg, Man., _O Dairy Ration_ (no guaranty, analyses 19.8); _Ogilvie's_ (17). Pillsbury Flour Mills Co., Minneapolis, Minn., _Pillsbury's A (Standard Brown with Low Grade Flour)_* (15); _Standard B_* (14); _Dairy XX_ (16); _Daisy_ (13). Quaker City Flour Mills Co., Philadelphia, Pa., ———— (14). Russell-Miller Milling Co., Minneapolis, Minn., _Alta (Standard and Flour)_ (15). St. Albans Grain Co., St. Albans, Vt., _Red Dog_ (no guaranty, analysis 19.9); _Wirthmore_ (14). St. Paul Milling Co., St. Paul, Minn., _Komo Standard_* (15). Slane Bros. & Wilson, Minneapolis, Minn., _Snowball Flour_* (16); _Rye_ (15.5). H. A. Slayton & Co., Morrisville, Vt., ———— (no guaranty, analysis 20.3). David Stott Flour Mills, Inc., Detroit, Mich., _Pennant_* (15); _Rye_ (10). Washburn-Crosby Milling Co., Minneapolis, Minn., _Standard_* (14). Western Canada Flour Mills Co., Ltd., Winnipeg, Man., _Shorts_ (17).

## WHEAT OFFALS—WHEAT MIXED FEED

### PROTEIN GUARANTIES FULFILLED

Amendt Milling Co., Monroe, Mich., _Amco_ (15); _Amco Stock_ (17). E. W. Bailey & Co., Montpelier, Vt., _Fancy_ (15), (15); _Capital_ (14). Caledonia Mills, Inc., St. Johnsbury, Vt., _Brook's Fancy_ (16). E. Crosby & Co., Brattleboro, Vt., _Crosby's_ (16). Federal Milling Co., Lockport, N. Y., _Dairy Maid_* (13). E. T. & H. K. Ide, St. Johnsbury, Vt., _Ideal Fancy_* (15), (15). International Milling Co., Minneapolis, Minn., _Black Hawk_ (13). F. W. Kelley Co., St. Johnsbury, Vt., _Bluetag_* (15). Lawrenceville Roller Mills Co., Lawrenceburg, Ind., _Golden Bull_* (16). National Milling Co., Toledo, O., _Osota_* (15); _Pennant_ (15). Northwestern Consolidated Milling Co., Minneapolis, Minn., _Plain_ (15). Pillsbury Flour Mills Co., Minneapolis, Minn., _Daisy_ (13); _Fancy_* (14). Portland Milling Co., ————, _Champion_* (13.55). Quaker Oats Co., Chicago, Ill., _Buckeye_*† (15.5). Russell-Miller Milling Co., Minneapolis, Minn.,

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*With ground screenings not exceeding mill run.
‡Including rye middlings.

*Occident* (15), (15). St. Albans Grain Co., St. Albans, Vt., *Wirthmore** (15); *Welden**‡ (12); *Franklin** (15). F. W. Stock & Sons, Hillsdale, Mich., *Monarch** (16); *Superior** (16). Stratton & Co., Concord, N. H., *Stratton's** (15.29). Williams Bros. Co., Kent, O., *Kent* (14).

## WHEAT OFFALS—RED DOG FLOUR

### PROTEIN GUARANTIES FULFILLED

Larabee Flour Milling Co., Kansas City, Mo., ———— (15). Northwestern Consolidated Milling Co., Minneapolis, Minn., *XXX Comet* (18). Northwestern Consolidated Milling Co., Minneapolis, Minn., *Comet* (16). St. Albans Grain Co., St. Albans, Vt., ———— (no guaranty, analysis 19.3). Slane Bros. & Wilson, Minneapolis, Minn., ———— (no guaranty, analysis 18.2). Washburn-Crosby Co., Minneapolis, Minn., *Arlington* (14). Washburn-Crosby Co., Minneapolis, Minn., *Adrain* (16).

## OAT HULLS, ETC.

### PROTEIN GUARANTIES FULFILLED

Ogilvie Flour Mills Co., Ltd., Winnipeg, Man., *Ogilvie's Oat Meal Feed* (4.75). Purity Oats Co. of Keokuk, Keokuk, Iowa, *Purity Oat Feed* (5). Quaker Oats Co., Chicago, Ill., *Oat Hulls Ground* (5); *Vim Feed* (5).

## HOMINY FEEDS

### PROTEIN GUARANTIES FULFILLED

American Hominy Co., Indianapolis, Ind., *Homco* (10). Plymouth Milling Co., Le Mars, Iowa, ———— (8.5). Quaker Oats Co., Chicago, Ill., *Yellow* (10.5).

## ALFALFA MEAL

### PROTEIN GUARANTY FULFILLED

Denver Alfalfa Milling & Products Co., Lamar, Colo., ———— (12).

## DRIED BEET PULP

### PROTEIN GUARANTY FULFILLED

Larrowe Milling Co., Detroit, Mich., ———— (8).

## PROPRIETARY FEEDS—DAIRY

### PROTEIN GUARANTIES FULFILLED

American Milling Co., Peoria, Ill., *Amco* (25). Armour Grain Co., Chicago, Ill., *Armour's* (22). E. W. Bailey & Co., Montpelier, Vt., *Capital* (23). Chapin & Co., Hammond, Ind., *Lactola* (16.5); *Unicorn* (24). Clover Leaf Milling Co., Buffalo, N. Y., *Dairy* (16); *Grain Ration* (24); *Peerless* (guaranty —, analysis 21.5). E. Crosby & Co., Brattleboro, Vt., *Ready Ration* (25). Cooperative G. L. F. Exchange, Inc., Buffalo, N. Y., *Orange Exchange* (22). Elmore Milling Co., Oneonta, N. Y., *Elmore Milk Grains* (25). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (24); *Krackerjack* (20). International Sugar Feed Co., Minneapolis, Minn., *International Special* (15). Kasco Mills, Inc., Toledo, O., *Big Repeater Ready Ration* (22), (22), (22). F. D. Lapelle, Swanton, Vt., *23% Dairy Ration* (23); *20% Dairy Ration* (20). Larrowe Milling

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*With ground screenings not exceeding mill run.
‡Including corn meal.

Co., DETROIT, MICH., *Larro Feed* (20), (20); *Larro Ready Ration* (22); *Big Six Complete* (21). MARATIME TRADING CORPORATION, BUFFALO, N. Y., *Bull Brand* (24); *Hitest* (20). PARK & POLLARD CO., BOSTON, MASS., *Stevens' 44* (24). PILLSBURY FLOUR MILLS CO., MINNEAPOLIS. MINN., *Pillsbury's* (19). QUAKER OATS CO., CHICAGO, ILL., *Big Q*. (21), (21), (21). RALSTON PURINA CO., INC., ST. LOUIS, MO., BUFFALO, N. Y., *Purina Cow Chow Feed* (24). ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Paragon* (22); *Farmer's Favorite* (25), (24); *Wirthmore Balanced Ration* (25), (25), (24). UBIKO MILLING CO., CINCINNATI, O., *Union Grains* (24); *Sunbeam* (20). UNITED STATES FOOD PRODUCTS CORPORATION, PEORIA, ILL., *Mel-O Farmer Jones Brand* (20); *Mel-O* (20). UNITED STATES FEED ASSOCIATION, TOLEDO, O., *Big Repeater* (22).

#### PROTEIN GUARANTIES NOT FULFILLED

ARCADY FARMS MILLING CO., CHICAGO, ILL., R. K. D. *Arcady* (guaranty 18, analysis 17.1). CHAPIN & CO., HAMMOND, IND., *Acorn* (guaranty 20, analysis 19). A. H. MCLEOD MILLING CO., ST. JOHNSBURY, VT., *Green Mountain* (guaranty 23, analysis 22.4).

### PROPRIETARY FEEDS—STOCK

#### PROTEIN GUARANTIES FULFILLED

E. W. BAILEY & CO., MONTPELIER, VT., *Pennant* (9). CHAPIN & CO., HAMMOND, IND., *Centaur* (12). CLOVER LEAF MILLING CO., BUFFALO, N. Y., *Black Beauty Horse* (10). E. CROSBY & CO., BRATTLEBORO, VT., *Crosby's* (9); *Zenith* (8.5). E. T. & H. K. IDE, ST. JOHNSBURY, VT., *Ideal* (10). INDIANA MILLING CO., TERRE HAUTE, IND., *Holstein* (10). CHAS. A. KRAUSE MILLING CO., MILWAUKEE, WIS., *Badger Monopoly* (9); *Badger* (10); *Krause* (9). F. D. LAPELLE, SWANTON, VT., ———— (9). PURITY OATS CO., DAVENPORT, IOWA, *Iowa* (10). QUAKER OATS CO., CHICAGO, ILL., *Schumacheer* (10). RALSTON PURINA CO., ST. LOUIS, MO., *Purina O—Molene* (9). ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Wirthmore* (9). DAVID STOTT FLOUR MILLS, INC., DETROIT, MICH., *Stott's Winner* (8.5). STRATTON & CO., CONCORD, N. H., *Stratton 24* (7.5). C. H. ULTLEY, HARDWICK, VT., *A* (no guaranty, analysis 17.1).

#### PROTEIN GUARANTIES NOT FULFILLED

AKRON FEED & MILLING CO., AKRON, O., *Portage* (guaranty 10, analysis 8.8). D. H. GRANDIN MILLING CO., JAMESTOWN, N. Y., *Grandin's* (guaranty 10. analysis 8.9). ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Charlestock* (guaranty 10, analysis 8.8). UNITED STATES FEED CO., MILWAUKEE, WIS., *U. S.* (guaranty 10, analysis 7.1).

### PROPRIETARY FEEDS—CALF

#### PROTEIN GUARANTIES FULFILLED

BLATCHFORD'S CALF MEAL CO., WAUHEGAN, ILL., *Blatchford's* (24). CLOVER LEAF MILLING CO., BUFFALO, N. Y., *Clover Leaf* (25). QUAKER OATS CO., CHICAGO, ILL., *Schumacher* (18). RALSTON PURINA CO., ST. LOUIS, MO., *Purina Calf Chow* (27). RYDE & CO., CHICAGO, ILL., *Ryde's Cream* (25).

### PROPRIETARY FEEDS—SWINE

#### PROTEIN GUARANTIES FULFILLED

CHAPIN & CO., HAMMOND, IND., *Bicorn* (17.5). PARK & POLLARD CO., BOSTON, MASS., *Go-Tuit* (15). RALSTON PURINA CO., ST. LOUIS, MO., *Purina Pig Chow* (15). ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Wirthmore* (17), (18), (18).

## PROPRIETARY FEEDS—POULTRY FEEDS—MASHES

### PROTEIN GUARANTIES FULFILLED

Blatchford's Calf Meal Co., Waukegan, Ill., *Milk Mash* (20). Clover Leaf Milling Co., Buffalo, N. Y., *Clover Leaf Egg* (18). E. Crosby & Co., Brattleboro, Vt., *Crosby's Egg* (16). Albert Dickinson Co., Chicago, Ill., *Globe Chick* (18). Elmore Milling Co., Oneonta, N. Y., *Elmore Egg* (18). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's Dry (with Buttermilk)* (20). Hales & Hunter Co., Chicago, Ill., *Red Corn and Egg* (16). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (20). Kasco Milling Co., Toledo, O., *Fullnest* (18.5). C. A. Krause Milling Co., Milwaukee, Wis., *Badger Laying* (18). F. D. Lapelle, Swanton, Vt., *Egg Producing* (18). Park & Pollard Co., Boston, Mass., *Lay or Bust* (18). Quaker Oats Co., Chicago, Ill., *Full-O-Pep* (20). St. Albans Grain Co., St. Albans, Vt., *Wirthmore Fish and Scrap with Milk Albumin* (20). W. R. White, North Bennington, Vt., *Flynn's* (18).

## PROPRIETARY FEEDS—POULTRY FEEDS—SCRATCH FEEDS

### PROTEIN GUARANTIES FULFILLED

American Milling Co., Peoria, Ill., *Cluck Cluck* (10). Armour Grain Co., Chicago, Ill., *Iroquois* (10). Berkshire Coal & Grain Co., North Adams, Mass., *Berkshire* (10). Clover Leaf Milling Co., Buffalo, N. Y., *Clover Leaf* (10). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's* (10). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (10). Kasco Mills, Waverly, N. Y., *Kasco* (10). C. A. Krause Milling Co., Milwaukee, Wis., *Badger Cream City* (9). R. H. McEwen Milling Co., Ogdensburg, N. Y., *McEwen's Red Feather* (no guaranty, analysis 10.5). Park & Pollard Co., Boston, Mass., *Red Feather* (10). Ralston Purina Co., St. Albans, Mo., *Purina* (10). Quaker Oats Co., Chicago, Ill., *Schumacher* (10). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (11).

## PROPRIETARY FEEDS—POULTRY FEEDS—CHICK FEEDS

### PROTEIN GUARANTIES FULFILLED

Clover Leaf Milling Co., Buffalo, N. Y., *Baby Chick* (10). E. Crosby & Co., Brattleboro, Vt., *Crosby's Chick* (9). Albert Dickinson Co., Chicago, Ill., *Globe Chick* (10). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's Baby Chick* (10). F. D. Lapelle, Swanton, Vt., *Baby Chick* (10). Park & Pollard Co., Boston, Mass., *Buttermilk Booster* (12); *Baby Buster Chick Gritless with Fish* (11); *Red Ribbon* (10); *Baby Buster* (11); *Intermediate* (10). Quaker Oats Co., Chicago, Ill., *Ful-O-Pep* (14); *Schumacher* (10). Raston Purina Co., St. Louis, Mo., *Purina* (10); *Purina Chicken Chowder* (11); *Purina Chicken Chowder with 1% Charcoal* (19). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (11); *Wirthmore Buttermilk Baby Chick* (13.5); *Wirthmore Gritless Chick* (11).

## PROPRIETARY FEEDS—POULTRY FEEDS—GROWING FEEDS

### PROTEIN GUARANTIES FULFILLED

D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's* (12.5). Park & Pollard Co., Boston, Mass., ———— (10). Quaker Oats Co., Chicago, Ill., *Full-O-Pep* (17); *Full-O-Pep Fattening* (16). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (15).

## PROPRIETARY FEEDS—POULTRY FEEDS—MISCELLANY

### PROTEIN GUARANTIES FULFILLED

Burlington Rendering Co., Burlington, Vt., *Beef Scraps* (40). Lowell Rendering Co., Lowell, Mass., *Peerless Poultry Food* (40). Carroll S.

Page, Hyde Park, Vt., *Ground Meat Scraps* (40). Portland Rendering Co., Portland, Me., *Portland Bone Meal for Cattle and Poultry* (20).

### PROTEIN GUARANTIES NOT FULFILLED

Innis, Speiden & Co.,* ————————, *Eg-O Milk Albumin* (guaranty 50, analysis 45.1).

## Discussion of the Results of Inspection

Samples were taken representing 48 brands of the high protein by-products (cottonseed and linseed meals, gluten feeds, brewers' etc. dried grains, peanut feeds), 9 brands of low protein products other than wheat offals (hominy feed, dried beet pulp, etc.), 97 brands of wheat offals (brans, middlings, mixed feeds, red dog flour) and 136 brands of proprietary brands (ready mixed rations for dairy cows, horses, poultry, calves, swine and stock in general).

| | Number of brands | Protein guaranties range from | Protein contents range from | Deficiencies | Unguaranteed |
|---|---|---|---|---|---|
| Cottonseed meals | 23 | 43 to 36 | 43.4 to 31.1 | 4 | 0 |
| Linseed meals | 12 | 36 to 30 | 36.8 to 29.9 | 4 | 0 |
| Gluten feeds | 8 | 23 | 28.8 to 23.7 | 0 | 0 |
| Distillers', etc., byproducts | 3 | 30 to 20 | 33.7 to 23.7 | 0 | 0 |
| Peanut feeds | 2 | 30 | 35.8 to 35 | 0 | 0 |
| Wheat offals | 97 | 19.3 to 11 | 19.8 to 13.8 | 0 | 5 |
| Wheat brans | 34 | 15.5 to 11 | 18.6 to 14 | 0 | 1 |
| Wheat middlings | 27 | 17.3 to 10 | 20.3 to 16.3 | 0 | 3 |
| Wheat mixed feeds | 29 | 16 to 13 | 18.9 to 13.8 | 0 | 0 |
| Red dog flours | 7 | 19.3 to 14 | 19.8 to 17.1 | 0 | 1 |
| Hominy feeds | 3 | 10.5 to 8.5 | 11.4 to 10.5 | 0 | 0 |
| Dried beet pulp | 1 | 8 | 9.2 | 0 | 0 |
| Alfalfa meal | 1 | 12 | 15.8 | 0 | 0 |
| Oat feeds, hulls, etc. | 4 | 5 to 4.75 | 7.7 to 4.8 | 0 | 0 |
| Corn meal | 2 | .. | 9.2 to 9 | .. | .. |
| Proprietary feeds | 136 | | | | |
| Dairy | 45 | 25 to 15 | 27.4 to 17.1 | 3 | 1 |
| Stock | 22 | 12 to 7.5 | 11.9 to 7.1 | 4 | 1 |
| Swine | 6 | 18 to 15 | 20.6 to 15.6 | 0 | 0 |
| Calf | 5 | 27 to 18 | 27.2 to 20.6 | 0 | 0 |
| Poultry | 58 | | | | |
| Mashes | 15 | 20 to 16 | 26.3 to 17.1 | 0 | 0 |
| Growing feeds | 5 | 17 to 10 | 21.9 to 18 | 0 | 0 |
| Scratch feeds | 14 | 11 to 9 | 11.2 to 10.1 | 0 | 1 |
| Chick feeds | 19 | 19 to 9 | 19.9 to 10.3 | 0 | 0 |
| General | 5 | 50 to 20 | 51.3 to 23.9 | 1 | 0 |
| Total | 290 | 50 to 4.75 | 51.3 to 4.8 | 16 | 3 |

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*Shipped by Geo. L. Harding Co., Inc., Binghamton, N. Y.

The outcome is not materially unlike that observed in former years; indeed it is distinctly better than has been sometimes noted. Only 11 brands out of nearly 300 showed deficiencies that can be regarded as serious. Four lots of cottonseed meal (F. W. Brodé Co.'s *Owl;* Buckeye Cotton Oil Co.'s *Good;* Cottonseed Oil Co.'s ———; and Union Seed and Fertilizer Co.'s *Yellow Tag*) contained, respectively, only 94, 86, 91 and 91 percents of the crude proteins they were guarantied to carry. One linseed meal, the Midland Linseed Products Co.'s goods carried only 84 percent of the promised protein contents. A bran sold by the Northwestern Consolidated Milling Co. carried only 88 percent of its promised protein. Four stock feeds (Akron Feed and Milling Co.'s *Portage,* D. H. Grandin Milling Co.'s *Grandin's,* St. Albans Grain Co.'s *Charlestock,* and the United States Feed Co.'s *U. S.*) contained, respectively, only 88, 89, 88 and 71 percents of their guarantied protein contents. A poultry feed (Innis, Speiden & Co.'s *Eg-O Milk Albumin*) carried only 90 percent of its promised protein.

This means that less than 3½ percent of the goods inspected were more than 5 percent deficient, and only 2 percent more than 10 percent deficient.

## AGRICULTURAL SEED INSPECTION

The Station sampling agents visited fully 40 Vermont cities, towns and villages during June, 1920, and gathered 362 samples of agricultural seed offered for sale in the open markets by local dealers as follows:

| | | | | | |
|---|---|---|---|---|---|
| **Alfalfa** | **5** | **Redtop** | **26** | **Peas, field** | **3** |
| **Barley** | **10** | **Timothy** | **80** | **Rape** | **2** |
| **Clover, alsike** | **38** | **Mixtures** | **5** | **Rye** | **1** |
| **Clover, red** | **61** | **Blue grass** | **2** | **Speltz** | **1** |
| **Corn** | **49** | **Buckwheat** | **2** | **Sweet clover** | **1** |
| **Millet** | **35** | **Clover, white** | **2** | **Sudan grass** | **3** |
| **Oats** | **32** | **Orchard grass** | **1** | **Wheat** | **3** |

These samples were drawn in accordance with the official directions. Purity tests were made by the weight method and the germination tests were made according to the method employed by the Federal Department of Agriculture.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| | | ALFALFA | | |
| IXL America | Conklin | 99.75 | 90 | 720 |
| Grimm's Globe | Holbrook | 99.5 | 85 | 90 |
| Pine Tree | Holbrook | 99 | 87 | 450 |
| Monadnock | Holbrook | 98 | 71 | 540 |
| Eureka | Whitney-Eckstein | 99.75 | 91 | 90 |
| | | BARLEY | | |
| Six-row | Bailey | *97.98* | 98 | 9 |
| ———— | Bailey | 95. | 98 | — |
| Liberty | Gunson | 99.15 | 99.5 | — |
| Liberty | Gunson | 99.15 | 94 | — |
| White Mountain | Holbrook | 98 | 98.5 | 36 |
| Ontario Six-row | St. Albans | 99 * | 86.5 | — |
| Ontario Six-row | St. Albans | 99 * | 92 | 36 |
| Six-row | Stanford | 95 | 100 | — |
| Six-row | Stanford | 95 | 98.5 | — |
| ———— | Stanford | 95 | 96 | 19 |
| | | ALSIKE CLOVER | | |
| ———— | Bailey | 96.25 | 97 | 4050 |
| C. M. | Berkshire | *97.9* | 89 | 4275 |
| Ace | Burdett | 96 | 80 | 7200 |
| ———— | Caledonia | *98* | 97 | 1125 |
| C. M. | Conklin | 95 | 88 | 1800 |
| C. M. | Conklin | 95 | 82 | 1125 |
| Imperial | Conklin | 97.5 | 87 | 3150 |
| Globe | Craver-Dickinson | 99.05 | 88 | 675 |
| Ace | Dickinson | 96.25 | 85 | 675 |
| Pine Tree | Dickinson | 96.3* | 80 | 2925 |
| ———— | Dickinson | 95.3 | 89 | 18450 |
| ———— | Dickinson | 96.45 | 85 | 11925 |
| Ace | Dickinson | 94.5 | 81 | 7200 |
| White Mountain | Holbrook | 98.5 | 87 | 900 |
| ———— | Holbrook | 93 | 76 | 11700 |
| XXX | Holbrook | 93 | 92 | 5850 |
| Pine Tree | Holbrook | 96 | 83 | 1350 |
| White Mountain | Holbrook | 98.5 | 89 | 2475 |
| White Mountain | Holbrook | 98.5 | 88 | — |
| ———— | Slayton | 90 | 83 | 6525 |
| Arc | Stanford | 94.5 | 80 | 8100 |
| Liberty | Stanford | 97.2 | 88 | 675 |
| 3369 | Stanford | 95 | 77 | — |
| ———— | Stanford | 99 * | 86 | 4275 |
| Liberty | Stanford | 96 | 82 | 4725 |
| 3373 | Stanford | 96.75 | 84 | 5625 |

*BELOW GUARANTY. *Barley.* St. Albans Grain Co., St. Albans, Vt.; Ontario Six-row; guaranty 99, found 98.1, 97.9. *Alsike Clover.* Albert Dickinson Seed Co., Chicago, Ill.; Pine Tree; guaranty 96.3, found 95.5. Stanford Seed Co., Buffalo, N. Y.; ————; guaranty 99, found 96.25.

*Italics* in the "purity guaranty" column indicate that no guaranties were found attached to the goods as offered for sale. This does not mean necessarily that the wholesaler did not furnish a guaranty as required by law. Most of the seed trade is very scrupulous in this respect. It means simply that the sampling agents noted no purity guaranties attached to the packages from which samples were drawn. The actual contents of pure seed found in each case is indicated in italics, since no guaranty statement can be furnished.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Honor | Stanford | 96 | 87 | 3150 |
| Pine Tree | Varick | 98 * | 81 | 7425 |
| Eureka | Whitney-Eckstein | 98 | 81 | 4725 |
| Eureka | Whitney-Eckstein | 98 | 90 | 6525 |
| ———— | Whitney-Eckstein | 98.5* | 90 | 4725 |
| Pan-American | Whitney-Eckstein | 98 * | 92 | 7875 |
| Eureka | Whitney-Eckstein | 97 | 94 | 10350 |
| Pan-American | Whitney-Eckstein | 97 | 88 | 1350 |
| Eureka | Whitney-Eckstein | 98 | 85 | 6975 |
| Eureka | Whitney-Eckstein | 98 | 89 | 7200 |
| Pan-American | Whitney-Eckstein | 97 * | 79 | 6075 |
| ———— | ———— | 97.5 | 92 | 675 |
| | | **RED CLOVER** | | |
| ———— | Abbott | 99 | 93.5 | 1890 |
| Mammoth | Amer. Mutual | 99 | 90.5 | 630 |
| ———— | Bailey | 99 | 94 | 270 |
| Atlas | Berkshire | *98.2* | 94.5 | 4320† |
| ———— | Caledonia | *99.58* | 91.5 | 990 |
| ———— | Caledonia | *99.6* | 85 | 270 |
| Crown (Mammoth) | Conklin | 99.35 | 94 | 360 |
| Paragon | Conklin | 98.25 | 97.5 | 1080 |
| Crown (Mammoth) | Conklin | 99.35 | 95.5 | 270 |
| Crown | Conklin | 99.35 | 97 | 270 |
| Ace | Craver-Dickinson | 98.5 | 93 | 720 |
| Globe | Craver-Dickinson | 99.44 | 93.5 | 270 |
| 2577 | Craver-Dickinson | 98.5 | 88.5 | 1530† |
| ———— | Craver-Dickinson | 97.6 | 91 | 2610 |
| Globe | Dickinson | 99.5 | 91 | 360 |
| Pine Tree | Dickinson | 98.5 | 97 | 2160 |
| Pine Tree | Dickinson | 99.5 | 90.5 | 810 |
| Ace 173737 | Dickinson | 99 | 94.5 | 1530 |
| Medium | Dickinson | 99.55 | 81.5 | 630 |
| Queen | Dickinson | 89.2 | 94.5 | 10710† |
| White Mountain | Holbrook | 99.5 | 90 | 450 |
| XXX | Holbrook | *99.6* | 97 | 1620 |
| Pine Tree | Holbrook | 99 | 91.5 | 630 |
| Pine Tree | Holbrook | 99 | 89 | 2970 |
| White Mountain | Holbrook | 99.5 | 87.5 | 900 |
| Green Mountain | Holbrook | 93 | 90.5 | 720 |
| Arc | Holbrook | 97 | 88 | 450 |
| XX | Holbrook | 95 | 92 | 6390 |
| Globe | Nung.-Dick. | 99.34 | 93 | 360 |
| ———— | Slayton | 89.2* | 93 | 180† |
| Arc Medium | Stanford | 98 | 96 | 1530 |
| Arc Medium | Stanford | 98 | 95 | 3240 |

*BELOW GUARANTY. *Alsike Clover.* J. B. Varick Co., Manchester, Vt.; Pine Tree; guaranty 98, found 96.75. Whitney-Eckstein Co., Buffalo, N. Y.; Pan-American; guaranty 98, found 97; guaranty 97, found 96.5; ————; guaranty 98.5, found 97.5. *Red Clover.* H. A. Slayton & Co., Morrisville, Vt.; ————; guaranty 89.2, found 80.5.

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†Contained dodder.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Bemis A Extra Heavy | Stanford | 99 | 95.5 | 270 |
| 3352 | Stanford | 99.15 | 86 | .. |
| Arc 4032 | Stanford | 98 | 94.5 | 1530 |
| — | Stanford | 98.5 | 81.5 | 90 |
| Liberty | Stanford | 98 | 90.5 | 2520 |
| 3354 | Stanford | 98 | 94.5 | 360 |
| Honor | Stanford | 98 | 94.5 | 450 |
| Arc | Stanford | 99 | 94 | 450 |
| Honor | Stanford | 99.3 | 94.5 | 360 |
| Arc | Stanford | 98 | 92.5 | 360 |
| Pine Tree | Varick | 98 | 85 | 2880 |
| Pine Tree | Varick | *99.88* | 86.5 | 90 |
| Eureka | Whitney-Eckstein | 99.5 | 95.5 | 900 |
| — | Whitney-Eckstein | 98 | 95.5 | 3420 |
| — | Whitney-Eckstein | 99.5* | 95 | 2520 |
| Pan-American | Whitney-Eckstein | 98.5 | 94.5 | 270 |
| Whit.-Eck. Choice | Whitney-Eckstein | 97 * | 92 | 7110 |
| Eureka | Whitney-Eckstein | 99.25 | 95 | 1350 |
| Pan-American | Whitney-Eckstein | 98 | 94.5 | 810 |
| Pan-American | Whitney-Eckstein | *98.76* | 96 | 3060 |
| Eureka | Whitney-Eckstein | 99.3 | 96.5 | 1440 |
| Pan-American | Whitney-Eckstein | 98.5 | 97.5 | 1080 |
| Eureka | Whitney-Eckstein | 99.5 | 95 | 180 |
| Eureka | Whitney-Eckstein | 99.3 | 94.5 | 2700 |
| Pan-American | Whitney-Eckstein | 98 | 92 | 1710 |
| Thrift | Stanford | 99.15 | 93.5 | 1080 |
| Liberty | Stanford | 98 | 90 | 1620 |
| — | — | 86 | 88 | 7920† |
| — | — | 86 | 88 | 8100 |
| | CORN | | | |
| Leaming | Bailey | 98 | 100 | — |
| King Philip | Bailey | 95 | 87 | — |
| Leaming | Bailey | *99.4* | 93 | — |
| Red Cob Fodder | Bailey | 98 | 98 | — |
| Improved Leaming | Bailey | 98 | 96 | — |
| King Philip | Bailey | 95 | 95 | — |
| Sanford White Flint | Bailey | 93 | 95 | — |
| Minnesota King | Bailey | 96 | 96 | — |
| Yellow Flint | Caledonia | *99.28* | 100 | — |
| Mammoth Yellow Flint | Caledonia | *98.82* | 96 | — |
| Gold Nugget | Caledonia | *98.5* | 76 | — |
| — | Cobb | 98 | 96 | — |
| — | Cobb | 98 * | 98 | — |
| — | Cobb | 98 * | 94 | — |
| Early Wonder | Conklin | 99.2 | 96 | — |
| Imp. Pride of North | Conklin | 99.12* | 88 | — |
| Sanford Flint | Dickinson | 99.5 | 97 | — |
| Pride of North | Dickinson | 99.8* | 92 | — |

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*BELOW GUARANTY. *Red Clover.* Whitney-Eckstein Co., Buffalo, N. Y.; Whitney-Eckstein Choice; guaranty 97, found 95.4; ————; guaranty 99.5, found 98.4. *Corn.* W. F. Cobb & Co., ————; ————; guaranty 98, found 95.3, 97.4. E. W. Conklin & Co., Binghamton, N. Y.; Improved Pride of the North; guaranty 99.12, found 98.6.

*Italics* in the "purity guaranty" column indicate that no guaranties were found attached to the goods as offered for sale. This does not mean necessarily that the wholesaler did not furnish a guaranty as required by law. Most of the seed trade is very scrupulous in this respect. It means simply that the sampling agents noted no purity guaranties attached to the packages from which samples were drawn. The actual contents of pure seed found in each case is indicated in italics, since no guaranty statement can be furnished.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| **Early Rochester** | Gunson | 99.87 | 99 | — |
| **Genesee Giant** | Gunson | 99.84* | 94 | — |
| **Pride of Nishua** | Gunson | 99.97* | 87 | — |
| **Pride of Nishua** | Gunson | 99.97 | 93 | — |
| ——— | Gunson | 99.84* | 98 | — |
| **Pride of Nishua** | Gunson | 99.97 | 88 | — |
| **Early Michigan** | Gunson | 99.87 | 92 | — |
| **Pride of Nishua** | Gunson | 99.97* | 94 | — |
| **Golden Ensilage** | Higbee | 99.24 | 96 | — |
| **Early Ensilage** | Higbee | 99.24 | 100 | — |
| **Rising 80-day Spec.** | Holbrook | 100 | 99 | — |
| **Rising Gold Dollar** | Holbrook | 100 * | 95 | — |
| **Rising Early King** | Holbrook | 100 | 93 | — |
| **Rising North Star** | Holbrook | 100 * | 100 | — |
| **Early King** | Landon | 100 | 100 | — |
| **Longfellow Yel. Flint** | Lapelle | 96 | 100 | — |
| **Leaming** | Ross | *99.69* | 97.5 | — |
| **Sanford Flint** | Ross | *99.3* | 97 | — |
| ——— | Stanford | 95 | 99 | — |
| **Early Triumph** | Stanford | 95 | 88 | — |
| **Luce's Favorite** | Stanford | 95 | 82 | — |
| **Pride of North** | Stanford | 95 | 86 | — |
| **Leaming** | Stanford | 95 | 98 | — |
| **White Flint** | Stanford | 95 | 96 | — |
| **3417** | Stanford | 95 | 89 | — |
| **Gold Dollar** | Stanford | 100 | 94 | — |
| **Yellow Leaming** | Stanford | 99 | 98 | — |
| ——— | Surprise | 100 | 71 | — |
| **Red Cob Ensilage** | Whitney-Eckstein | 98 | 92 | — |
| **Early Mastadon** | Whitney-Eckstein | 98 | 96 | — |
| **Sanford White Flint** | Woodruff | *100* | 98 | — |

MILLET

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| **Japanese** | Abbott | 99 | 93.5 | 900 |
| **Japanese** | Amer. Mutual | 86.59 | 67 | 12060 |
| **Japanese (A)** | Bailey | 98.8* | 89.5 | 2970 |
| **Hungarian** | Bailey | 99.5 | 86 | 2340 |
| **Japanese** | Cobb | 98 | 97 | 900 |
| **Hungarian** | Conklin | 90 | 92 | 900 |
| ——— | Conklin | 97.1 | 98 | 7560 |
| **Japanese** | Craver-Dickinson | 98.04 | 94 | 2520 |
| **Japanese** | Craver-Dickinson | 99 | 94 | 1620 |
| **Hungarian** | Dickinson | 99.3 | 95 | 180 |

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*BELOW GUARANTY. *Corn.* Albert Dickinson Co., Chicago, Ill.; Pride of North; guaranty 99.8, found 98.3. L. P. Gunson Co., Rochester, N. Y.; Genesee Giant; guaranty 99.84, found 97.9; Pride of Nishua; guaranty 99.97, found 97, 97.7; ———; guaranty 99.84, found 96.7. Holbrook Grocery Co., Keene, N. H.; Rising's Gold Dollar; guaranty 100, found 98.5; Rising's North Star; guaranty 100, found 99.5. *Millet.* E. W. Bailey & Co., Montpelier, Vt.; Japanese (A); guaranty 98.8, found 97.8. Holbrook Grocery Co., Keene, N. H.; Japanese; guaranty 97, found 96.2.

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| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Hungarian | Dickinson | 99.75 | 95.5 | 630 |
| Hungarian | Dickinson | 99.3 | 95 | 630 |
| Japanese | Dickinson | 98.65 | 93.5 | 1260 |
| ———— | Dickinson | 96.25 | 81 | 4140 |
| Japanese | Gunson | 97.78 | 94.5 | 360 |
| Japanese | Gunson | 97.78 | 95 | 3150 |
| Hungarian | Holbrook | 97 | 97.5 | 1890† |
| Hungarian | Holbrook | 97 | 89.5 | 2970 |
| Hungarian | Holbrook | 95 | 83.5 | 1170 |
| Japanese | Holbrook | 97 * | 82.5 | 2520 |
| Hungarian | Stanford | 98 | 98.5 | 630 |
| Japanese | Stanford | 98 | 79.5 | 3780 |
| Japanese | Stanford | 95 | 91 | 5850 |
| Hungarian | Whitney-Eckstein | 97 | 82 | 2880 |
| Hungarian | Whitney-Eckstein | 98.5 | 93.5 | 2772 |
| Hungarian | Whitney-Eckstein | 97 | 98.5 | 4320 |
| Japanese | Whitney-Eckstein | 98 * | 87.5 | 2250 |
| Japanese | Whitney-Eckstein | 97 | 88 | 3330 |
| Japanese | Whitney-Eckstein | 97 | 77 | 2880 |
| Japanese | Whitney-Eckstein | 97 * | 80.5 | 2340 |
| Japanese | Whitney-Eckstein | 97 * | 83.5 | 3960 |
| Japanese | Whitney-Eckstein | 97 | 86.5 | 2160 |
| Japanese | Whitney-Eckstein | 97 | 94.5 | 3690 |
| Japanese | Whitney-Eckstein | 96 | 94 | 5490 |
| Japanese | ———— | *98.6* | 92.5 | 1260 |
| | OATS | | | |
| Pennant | Bailey | 99.5 | 97.5 | 32 |
| Pennant | Bailey | 99.5 | 100 | — |
| Pennant | Bailey | 99.5 | 99 | 18 |
| Pennant | Bailey | 99.5 | 92.5 | 27 |
| Pennant | Bailey | 99.5 | 99 | — |
| Pennant | Bailey | 99.5 | 99 | — |
| ———— | Berkshire | 90 | 95 | 98 |
| Recleaned | Burdett | 99.78 | 99 | 99 |
| ———— | Caledonia | *97.81* | 97 | 33 |
| Swedish | Caledonia | *99.44* | 91 | 144 |
| ———— | Caledonia | *99.43* | 98.5 | 44 |
| Michigan 2 White | Chatterton | *99.7* | 97 | 9 |
| ———— | Cobb | 98 * | 99.5 | — |
| Crosby's Recleaned | Crosby | 99.78* | 99 | 27 |
| ———— | Dickinson | 99.5 | 99 | — |
| Royal Banner | Gunson | 99.78 | 94 | — |
| Granary Filler | Gunson | 99.78 | 98.5 | — |
| Mammoth Cluster | Gunson | 99.78 | 95.5 | — |
| Prince Royal | Gunson | 99.78 | 97.5 | — |
| Liberian Cluster | Higbee | 99.77 | 97 | 45 |
| Granary Filler | Higbee | 99.5* | 99 | 9 |

*BELOW GUARANTY. *Millet.* Whitney-Eckstein Co., Buffalo, N. Y.; Japanese; guaranty 98, found 97.2; guaranty 97, found 96, 95.6. *Oats.* W. F. Cobb & Co., ————; ————; guaranty 98, found 95.4. E. Crosby & Co., Brattleboro, Vt.; ————; guaranty 99.78, found 98.9.

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†Smut present.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| **White Mountain** | Holbrook | 99 | 99.5 | — |
| **White Mountain** | Holbrook | 99 | 98.5 | — |
| **Extra Fancy** | Holbrook | 99 | 100 | — |
| **White Mountain** | Holbrook | 99 | 100 | — |
| **White Mountain** | Holbrook | 99 | 92 | — |
| **White Mountain** | Holbrook | 99 | 99 | — |
| **White Mountain** | Holbrook | 99 | 98 | — |
| **White Mountain** | Holbrook | 99 | 100 | 9 |
| ——— | Park & Pollard | *98.58* | 88 | 18 |
| **Hygrade Fancy** | St. Albans | 99 | 99 | 90 |
| **Hygrade Fancy** | St. Albans | 99 | 96 | 207 |
| | RED TOP | | | |
| **Ace** | ‡Bailey | 97.25* | 85 | 17550† |
| ——— | Caledonia | *97* | 48 | 10800 |
| ——— | Caledonia | *96* | 44 | 8550 |
| **No. 1** | Conklin | 85 | 47 | 99000 |
| **Imperial** | Conklin | 93.75 | 73 | 17100 |
| **A** | Conklin | 85 | 49 | 92250 |
| **Ace** | Craver-Dickinson | 92.3 | 58 | 18000 |
| **2156** | Craver-Dickinson | 90 | 74 | 32400† |
| ——— | Dickinson | 90 | 73 | 30150† |
| **Ace** | Dickinson | 90 | 42 | 17550 |
| **Ace** | Dickinson | 92.6 | 60 | 23400† |
| **Ace** | Holbrook | 90 | 59 | 19350 |
| **White Mountain** | Holbrook | 95 | 81 | 24750 |
| **Fancy 4171** | Stanford | 85 | 67 | 261000 |
| ——— | Stanford | 85 | 46 | 231300 |
| ——— | Stanford | 87 | 69 | 18900 |
| **Fancy** | Stanford | 93 | 57 | 3150 |
| **4010** | Stanford | 87 | 62 | 19800 |
| **Pan-American** | Whitney-Eckstein | 90 | 49 | 9900 |
| **Fancy** | Whitney-Eckstein | 90 | 62 | 37350† |
| **Eureka** | Whitney-Eckstein | 95 | 63 | 6300 |
| **Pan-American** | Whitney-Eckstein | 90 | 43 | 15300 |
| **Whit.-Eck. Fancy** | Whitney-Eckstein | 90 | 55 | 1800 |
| **Pan-American** | Whitney-Eckstein | 90 | 59 | 1800 |
| **Eureka** | Whitney-Eckstein | 94 | 59 | 11250 |
| **Eureka** | Whitney-Eckstein | 95 * | 47 | 26550 |
| | TIMOTHY | | | |
| **Mastiff** | Abbott | *99.65* | 92 | 225 |
| ——— | Amer. Mutual | 99.15 | 94 | 1800 |
| **Pine Tree** | Berkshire | *99.7* | 84 | — |
| **Pine Tree** | Burlington | *99.5* | 83 | 225 |
| **XX** | Burlington | 98 | 87 | 3825 |
| ——— | Caledonia | *99.75* | 93 | 450 |
| **King** | Conklin | 99.6 | 92 | 1125 |
| **King** | Conklin | 99.6 | 88 | 900 |

*BELOW GUARANTY. G. K. Higbee Co., ———; Granary Filler; guaranty 99.5, found 96.3. *Red Top.* E. W. Bailey & Co., Montpelier, Vt.; Ace; guaranty 97.25, found 94.7. Whitney-Eckstein Co., Buffalo, N. Y.; Eureka; guaranty 95, found 91.

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†Ergot present. ‡Presence of ergot declared in guaranty.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| King | Conklin | 99.6 | 82 | 450 |
| State | Conklin | 99.7 | 63 | 1125 |
| King | Conklin | 99.6 | 89 | 225 |
| Bingo | Conklin | 99.9 | 88 | 225 |
| King | Conklin | 99.6 | 85 | 450 |
| Spear | Conklin | 97 | 73 | 23850 |
| State | Conklin | 99.7 | 77 | 225 |
| Pine Tree | Conklin | 99.6 | 92 | 225 |
| King | Conklin | 99.6 | 76 | — |
| Ace | Craver-Dickinson | 99.5 | 87 | 225 |
| ———— | Craver-Dickinson | 99.6 | 84 | 450 |
| Pine Tree | Craver-Dickinson | 99.5 | 60 | 450 |
| ———— | Craver-Dickinson | 99.1 | 95 | 3375 |
| Pine Tree | Dickinson | *99.5* | 96 | 225 |
| Pine Tree | Dickinson | 99.6 | 90 | — |
| Pine Tree | Dickinson | 99.6 | 90 | — |
| Pine Tree | Dickinson | 99.6 | 91 | — |
| Globe | Dickinson | 99.8 | 94 | — |
| Globe | Dickinson | 99.8 | 92 | 450 |
| ———— | Dickinson | 99.6 | 91 | 450 |
| Pine Tree | Dickinson | 99.6 | 92 | 225 |
| ———— | Dickinson | 99.6 | 88 | — |
| Pine Tree | Dickinson | 99.6 | 90 | — |
| Bison | Dickinson | 98 | 86 | 900 |
| Bison | Dickinson | *97.5* | 86 | 3600 |
| XX | Holbrook | 98 | 75 | 3600 |
| Pine Tree | Holbrook | 99.5 | 89 | 225 |
| Old Home | Holbrook | 98 | 95 | 2475 |
| Pine Tree | Holbrook | 99.6 | 97 | 225 |
| White Mountain | Holbrook | 99.85 | 88 | 225 |
| White Mountain | Holbrook | 99.85 | 84 | — |
| Pine Tree | Holbrook | 99.6 | 81 | 225 |
| White Mountain | Holbrook | 99.85 | 87 | 225 |
| XX | Holbrook | 93 | 92 | 1125 |
| White Mountain | Holbrook | 99.85 | 91 | — |
| White Mountain | Holbrook | 99.85 | 76 | — |
| Pine Tree | Landon | *99.7* | 93 | 225 |
| Pine Tree | Middlebrook | 99.5 | 79 | 675 |
| Honor | Stanford | 99.7 | 95 | 675 |
| Liberty | Stanford | 99.5 | 91 | — |
| Liberty | Stanford | 99.5 | 92 | 450 |
| ———— | Stanford | 98 | 90 | 6525† |
| Liberty | Stanford | 99.5 | 93 | 450 |
| Honor | Stanford | 99.75 | 74 | — |
| Liberty | Stanford | 99.5 | 92 | 450 |
| Liberty | Stanford | 99.5 | 83 | 900 |
| Liberty | Stanford | 99.5 | 76 | —† |
| ———— | Stanford | 99.5 | 93 | 225 |
| Liberty | Stanford | 99.5 | 87 | — |
| ———— | Stanford | 99.5 | 68 | 225 |
| Liberty | Stanford | 99.25 | 89 | 225 |
| Pine Tree | Varick | 99.6 | 91 | — |
| Pine Tree | Varick | *99.9* | 87 | — |

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| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Pan-American | Whitney-Eckstein | 99.5 | 94 | — |
| Gold Medal | Whitney-Eckstein | 99.75 | 90 | — |
| Pan-American | Whitney-Eckstein | 99.5 | 92 | 450 |
| Pan-American | Whitney-Eckstein | 99.5 | 93 | 225 |
| Gold Medal | Whitney-Eckstein | 99.7 | 89 | — |
| Gold Medal | Whitney-Eckstein | 99.7 | 92 | 675 |
| Pan-American | Whitney-Eckstein | 99.5 | 87 | 225 |
| Gold Medal | Whitney-Eckstein | 99.75 | 92 | 900 |
| Imperator | Whitney-Eckstein | 99 | 80 | 3375† |
| Pan-American | Whitney-Eckstein | 99.5 | 94 | 225 |
| Gold Medal | Whitney-Eckstein | 99.75 | 85 | — |
| Gold Medal | Whitney-Eckstein | 99.75 | 87 | 225 |
| Imperator | Whitney-Eckstein | 99 | 81 | 450 |
| Pan-American | Whitney-Eckstein | *99.97* | 23 | 225 |
| Pan-American | Whitney-Eckstein | 99.5 | 95 | 675 |
| Gold Medal | Whitney-Eckstein | 99.75 | 90 | — |
| Pan-American | Whitney-Eckstein | 99.5 | 90 | — |
| Gold Medal | Whitney-Eckstein | 99.75 | 90 | — |
| Pan-American | Whitney-Eckstein | 99.5 | 91 | 450 |
| MIXTURES | | | | |
| Alsike, Red and White Clovers and Timothy | Conklin | 98 | 88 | 9000 |
| Alsike, Red and White Clovers and Timothy | Conklin | 98 | 75 | 6525 |
| Alsike and Timothy | Dickinson | 85.05T<br>10.2A | 92.5T<br>2.5A | 4050 |
| Red Top and Timothy | Whitney-Eckstein | 99.5 | 71 | 675 |
| MISCELLANEOUS | | | | |
| Ky. Blue Grass (Globe) | Dickinson | 84.5 | 35 | 7650 |
| Ky. Blue Grass | Dickinson | 73.5 | 37.5 | 900 |
| Buckwheat | Whitney-Eckstein | 98 | 82 | 325 |
| Buckwheat | Whitney-Eckstein | 98 | 99 | 250 |
| (White) Clover | Conklin | 95.5 | 98 | 2475 |
| (White) Clover | Dickinson | 91.15 | 86 | 2925 |
| Orchard Grass | Dickinson | 78 | 45 | 675 |
| Peas (Field) | Conklin | 99.32 | 66 | — |
| Peas (Canada) | Stanford | 95 | 90 | — |
| Peas (Canada) | Caledonia | *97.35* | 99 | — |
| Rape | Whitney-Eckstein | 98 | 90 | — |
| Rape | Whitney-Eckstein | 98 | 93.5 | — |
| Rye (Spring) | Middlebrook | 95 | 98 | 11 |
| Speltz | Gunson | 98.67* | 77 | — |
| Clover (Sweet) | Holbrook | 99 | 94 | 180 |
| Sudan Grass | Gunson | 99.17 | 87 | — |
| Sudan Grass | Gunson | 99.17 | 85.5 | — |
| Sudan Grass | Gunson | 99.17 | 88 | — |
| Sudan Grass | Higbee | 99.11 | 87.5 | — |
| Wheat | Bailey | 98 | 93 | 90 |
| Wheat | Cunningham | 90 | 99.5 | — |
| Wheat | Caledonia | *99.55* | 95 | — |
| Lawn Grass | Whitney-Eckstein | 80 | 49 | 38250 |

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*BELOW GUARANTY. Albert Dickinson Co., Chicago, Ill. *Alsike and Timothy;* guaranty, 85.05 timothy, 10.2 alsike; found 92.5 and 2.5. L. P. Gunson Co., Rochester, N. Y.; *Speltz;* guaranty 98.67; found 94.9.

*Italics* in the "purity guaranty" column indicate that no guaranties were found attached to the goods as offered for sale. This does not mean necessarily that the wholesaler did not furnish a guaranty as required by law. Most of the seed trade is very scrupulous in this respect. It means simply that the sampling agents noted no purity guaranties attached to he packages from which samples were drawn. The actual contents of pure seed found in each case is indicated in italics, since no guaranty statement can be furnished.

## DISCUSSION OF THE RESULTS OF INSPECTION

The violations of the law consist of:

(1) *Failure to declare guaranties.* This amounts to practical nullication, in so far as information touching guaranteed purity is concerned, supplied to the purchaser of the usual amounts from broken packages. The writer has no means of knowing with certainty but has every reason to believe that local merchants quite commonly fail to affix "a plainly written or printed statement," "conspicuously" to "every lot or parcel of agricultural seed of five pounds or over sold for seeding purposes" "clearly and truly certifying the namer thereof and its minimum percentage of purity," etc.

Nearly ten percent of the lots sampled by the station agents bore no visible statement as to the purity of their contents. Almost invariably this information is furnished by the wholesaler, but the retailer often pays no attention to and destroys it.

(2) *Failure to maintain guaranties.* Ten percent of the goods which were guaranteed were found to be deficient, and two percent were seriously deficient. Especial attention is called to the following cases. It is not to be wondered that there are several lapses in view of the extremely tenuous protection afforded by the Vermont law, which is about as toothless as it well can be.

*H. A. Slayton & Co.,* Morrisville, Vt. *Red Clover.* Guarantied 89.2, found 80.5. This lot contained 18.8% millet.

*W. F. Cobb & Co.,* ————. *Oats.* Guarantied 98, found 95.4. The impurity was mostly barley.

*G. K. Higbee Co.,* ————. *Oats, Granary Filler Brand.* Guarantied 99.5, found 96.3. This lot contained 3% wheat.

*E. W. Bailey & Co.,* Montpelier, Vt. *Red Top, Ace Brand.* Guarantied 97.25, found 94.7. Contained more than 5% inert matter.

*Whitney-Eckstein Co.,* Buffalo, N. Y. *Red Top, Eureka Brand.* Guarantied 95, found 91. Contained 8% inert matter.

*Albert Dickinson Co.,* Chicago, Ill. *Alsike and Timothy.* Guarantied to contain 85.05 timothy and 10.2 alsike; contained 9.25 timothy and 2.5 alsike. It is conceivable, of course, that mechanical separation occurred in the bag and that the entire sack carried the proportions indicated.

*L. P. Gunson Co.,* Rochester, N. Y. *Speltz.* Guarantied 98.67, found 94.9. Contained 4.8% inert matter.

## CONCERNING VIABILITY

The Vermont law does not require the seller to state the viability of his goods—as is done in New Hampshire and several other states. However, the Vermont Station has always reported upon this important matter. A considerable number of lots bore a guaranty statement as to viability. It is interesting to compare promise and performance, as follows:

| | Total number | Guaranteed | Guaranty met | Guaranty not met |
|---|---|---|---|---|
| **Alfalfa** .............. | 5 | 1 | 1 | 0 |
| **Barley** .............. | 10 | 3 | 3 | 0 |
| **Clover, alsike** ........ | 38 | 13 | 5 | 8 |
| **Clover, red** .......... | 61 | 21 | 18 | 3 |
| **Corn** ................ | 49 | 30 | 20 | 10 |
| **Millet** ............... | 35 | 12 | 7 | 5 |
| **Oats** ................ | 32 | 7 | 6 | 1 |
| **Red Top** ............. | 26 | 11 | 0 | 11 |
| **Timothy** ............ | 80 | 20 | 7 | 13 |
| **Mixtures** ............ | 5 | 0 | 0 | 0 |
| **Miscellaneous** ........ | 21 | 3 | 3 | 0 |
| | 362 | 121 | 70 | 51 |

It is clear that seed dealers hesitate to put upon the package "the truth, the whole truth and nothing but the truth" in respect to their red top sales; and there seems a tendency to overstate the viability of timothy.

How is it as between the different seed houses? Eighty percent of the samples were the product of seven concerns, and these houses guaranteed the viability of three-eighths of the lots sampled. Six of the seven were on the safe side, maintaining more guaranties than they failed to maintain. The three concerns which apparently sell most largely and which guaranteed the viability of from 3/10 to 7/10 of their goods, on the average exceeded their viability guaranties in 55% and did not exceed them in 45% of the cases.

COMPARISON OF VIABILITY WITH STANDARDS

| Seed | Standard of viability | Samples | Up to or above minimum standard | Below minimum standard |
|---|---|---|---|---|
| Alfalfa | 85-90 | 5 | 4 | 1 |
| Barley | 90-95 | 10 | 9 | 1 |
| Alsike clover | 75-80 | 38 | 38 | 0 |
| Red clover | 85-90 | 61 | 59 | 2 |
| Corn | 90-95 | 49 | 40 | 9 |
| Millet | 85-90 | 35 | 27 | 8 |
| Oats | 90-95 | 32 | 31 | 1 |
| Red top | 75-80 | 26 | 2 | 24 |
| Timothy | 85-90 | 80 | 60 | 20 |
| Buckwheat | 90-95 | 2 | 1 | 1 |
| Peas | 93-98 | 3 | 1 | 2 |
| Rape | 90-95 | 2 | 2 | 0 |
| Rye | 90-95 | 1 | 1 | 0 |
| | | 344 | 275 | 69 |

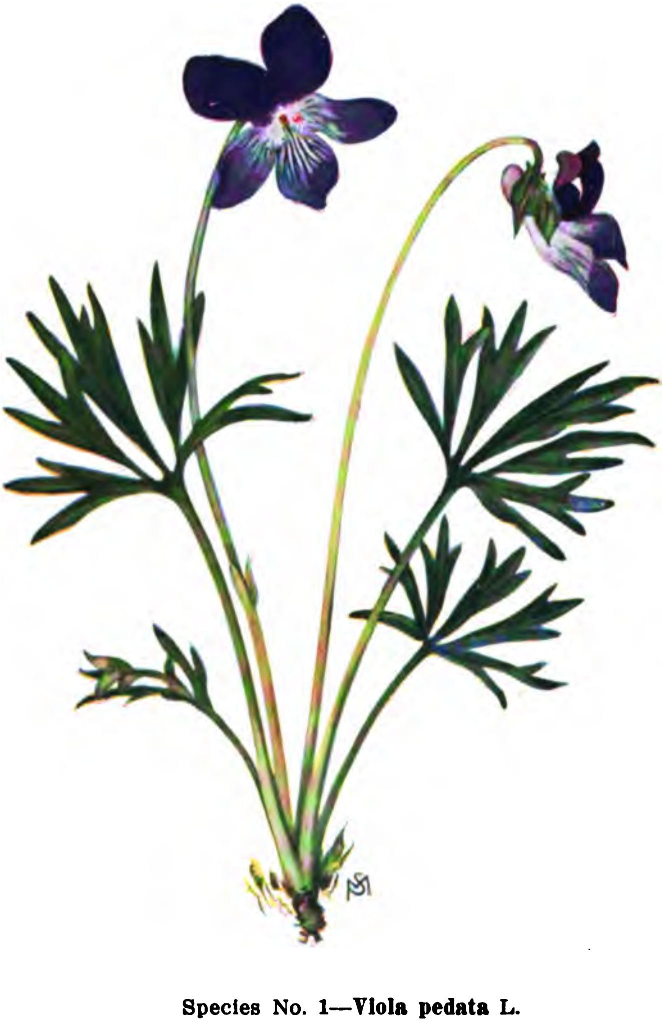
This outcome is, on the whole, a reasonably satisfactory one, 80 percent of the seed being of standard quality in respect to viability; that is to say, in other words, apart from all matter of guaranty maintenance, on the whole, viabilities were excellent in 1921—a very different situation than was found in 1920.

The following list is of bulletins issued during recent years, most of which have not been sent to the entire mailing list. Any one or more will be sent you, if desired, without charge. A postal card addressed to the Experiment Station, Burlington, stating your desires is sufficient.

| | | |
|---|---|---|
| 210 | A study of the frustrum form factors of hard maple and yellow birch | 38 pages |
| 211 | The aerial fertilization of plants with carbon dioxid | 56 pages |
| 212 | Thirty-first annual report (1917-1918) | 16 pages |
| 213 | Cold storage of cottage and other soft curd cheeses | 22 pages |
| 214 | Tipburn of the potato and other plants | 28 pages |
| 215 | Scab resistance of potato tubers | 30 pages |
| 216 | Commercial fertilizers; Commercial feeding stuffs; Agricultural seed (1919) | 16 pages |
| 217 | Blackberries of New England—Their classification | 84 pages |
| 218 | Blackberries of New England—Genetic status of the plants | 36 pages |
| 219 | Eccentric growth and the formation of redwood in the main stem of conifers | 16 pages |
| 220 | Commercial fertilizers; Commercial feeding stuffs; Agricultural seed (1920) | 32 pages |
| 221 | First 15 years of a 40-variety apple orchard. Apple cion selection from high and low yielding parent trees | 46 pages |
| 222 | Yield and quality in Hubbard squash | 48 pages |

The following bulletins are in press and will be issued in the near future. They will not be sent to the entire mailing list. Any one or more will be sent you, if desired, without charge. A postal card addressed to the Experiment Station, Burlington, stating your desires is sufficient.

| | | |
|---|---|---|
| 224 | The violets of North America (in press) | 60+ pages |
| 225 | Protein studies with dairy cows (in press) | 120+ pages |
| 226 | Maintenance studies with dairy cows (in press) | 120+ pages |



Species No. 1—**Viola pedata L.**

DECEMBER, 1921 BULLETIN 224

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# VIOLETS OF NORTH AMERICA

By EZRA BRAINERD

INTRODUCTION by GEORGE P. BURNS

1791

BURLINGTON
FREE PRESS PRINTING COMPANY
1921

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# BULLETIN 224: VIOLETS OF NORTH AMERICA

By Ezra Brainerd[1]

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## I. INTRODUCTION

By George P. Burns

It is not my purpose in this introduction to go into a detailed discussion of the problem of the origin of species, but only to outline the scope of the work reported in this bulletin and that of bulletins 217 and 218 of this Station as they relate to that question.

The method of the origin of new species is today the leading problem before those botanical workers who are interested in plant evolution. An explanation of the causes leading to those fundamental changes in a plant which botanists recognize as giving it specific rank is the most pressing of all evolutionary problems, important not only to those interested in pure science but also to those working in the field of plant breeding.

The beginning of the twentieth century may be justly regarded as an epoch making date in the history of botanical science. It was then that the validity of the theories of Mendel was first clearly recognized by botanists. The work of de Vries, who promulgated the theory of mutation and the principle of unit characters, appeared about this time. Focke and Sudre had already shown that hybridism had been responsible for numerous forms upon which evolution could work in the progress of plant life. Recently Lotsy has attacked the mutation hypothesis, claiming that all changes in living matter are due to hybridization and not to mutations. Two hypotheses, then, are now extant to account for the origin of new forms; the one maintaining that these arise spontaneously from existing species; the other claiming that changes in plants are due to recombinations of unit-characters due to hybridization. The number of possible combinations of unit-characters in the hybrid is always large, because each plant possesses many such unit-characters and the resulting hybrids are accordingly exceedingly variable. Hence it is of fundamental importance in any investigation which attempts a genetic study of the behavior of individual plants that, as a necessary preliminary step, an extended research be made to determine the antecedents of the individuals used.

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[1] President Emeritus of Middlebury College.

The most promising material growing in the wild for testing the value of either of these hypotheses would be a genus or genera in which there are well defined species with numerous intermediate forms—hybrids or elementary species. Two such polymorphic genera are Rubus and Viola. Brainerd has studied these two genera intensively for over 25 years. Early in his systematic work he became "painfully aware of the confusion that had arisen from publication of scores of obscure and illegitimate species in these two genera based on scanty or immature material."

His method in both genera has been the same. It consisted in:

(1) An examination of all the material in the principal herbaria.

(2) A comprehensive study of the distribution of the plants growing in their native habitats by means of many personal excursions and with the help of many co-laborers.

(3) An experimental analytical study of the individual plants.

(4) A synthetic study of the forms by crossing.

In later years Peitersen became associated with him in his study of Rubus and the work as outlined above was completed and the results published.[1] Brainerd has completed the first three phases of the work with Viola, but the fourth remains to be done.

From May, 1902 to October, 1903, Brainerd devoted his time principally to work in the field, collecting and examining some 2,000 to 3,000 plants from over 200 stations in western New England and western Massachusetts. Much of this material was examined and discussed by expert students of the genus. In his study of the literature he found that, for the most part, students of violets had not paid sufficient attention to the development of the plant during the summer months and he was the first to show the outstanding importance of studying the mature plant, bearing apetalous flowers and capsules.

Later, a wealth of material, consisting of living plants from all parts of the country, was collected in his garden and grown under similar cultural conditions to determine which variations found could be attributed to environmental factors and which to fundamental differences in the germ plasm. Some idea of the extent of his garden study may be gained from the fact that his collection consisted at one time of approximately 3,500 plants of about 650 different numbers, some 200 of which were from the wild and 450 raised from seeds.

---

[1] Vt. Sta. Buls. 217, 218 (1920).

These studies awakened his suspicion of hybridism and he published in 1914 his first triangle which aimed to express the genetic relationship of the violets of western Vermont. In fact, this triangle shows that in the five species which had been most thoroughly studied, were to be found eight of the ten possible hybrids that might result from their inbreeding.

When the idea that many of the intermediate plants might be hybrids was reached, an experimental method was at hand to test its truth. Thus it was possible for him to test the accuracy of his systematic work by sowing in his garden the seed from the various forms found there. In this way he was able to determine which were good, i. e., valid, species, which were hybrids and, furthermore, to determine the parents of any hybrid. This work was analytical. At present he has in his herbarium the enormous number of 984 sheets of specimens of violet hybrids from the wild and from garden cultures which represent 89 distinct hybrids.

The results of the work have been discussed as shown by the list of publications at the end of this bulletin. Some of the more important data may be summarized here. The numerous forms found in the wild may be grouped into three classes, species, hybrids and anomalous forms which are normally fertile and come true to seed. These last named forms are the result of hybridism in the remote or recent past. In this way new forms have arisen which, although of hybrid origin, are distinct and stable and, if fairly widespread, may be entitled to specific rank. His experimental work, with that of Peitersen, has shown the great wealth of new forms furnished by hybridization upon which natural selection may operate. This work represents one of the most illuminating researches of the present time, throwing light on the problem of the origin of species. It marks an enormous advance in the methods of the systematic botanist.

In view of the fact that the composition of plants found growing in the wild is so uncertain, I believe that such a study as is here presented is absolutely indispensable to determine the relationship of the species in any genus of plants. All work in plant breeding should be preceded by such a preliminary experimental analysis of the plants to be used as parents before actual breeding experiments are begun. Only thus can the experiments themselves be properly conducted; only thus can reliable results be secured.

We wish to acknowledge the assistance which W. W. Eggleston of the Bureau of Plant Industry has rendered in reading of proof and in checking references.

## II. VIOLETS OF NORTH AMERICA

### BY EZRA BRAINERD

*A.* Acaulescent or without manifest stems.
- *a.* Rootstock fleshy and thickened, without stolons.
  - *b.* Cleistogamous flowers in raceme-like branches.
    - Leaves of raceme one or less; seeds gray.
      41. **V. rotundifolia.**
    - Leaves of raceme several; seeds brown.
      42. **V. orbiculata.**
  - *bb.* Cleistogamous peduncles from rootstock.
    - *c.* Petals all beardless, apetalous flowers wanting, upper petals dark violet, others lilac-purple.
      1. **V. pedata.**
    - *cc.* Lateral petals bearded; cleistogamous flowers abundant; petals all normally violet-purple; freely hybridizing—only three species in Synoptical Flora.
      - 1. Cleistogamous flowers ovoid on short prostrate pedicels; capsules purplish.
        - Leaves usually cut.
          - Leaves all palmately 5-11-lobed or -parted.
            - Plants villous-pubescent.
              2. **V. palmata.**
            - Plants nearly or quite glabrous.
              - Seeds brown.
                3. **V. Egglestoni.**
              - Seeds buff.
                4. **V. Stoneana.**
          - Earliest and latest leaves usually uncut, others pedately 3-7-lobed; seeds generally buff.
            - Plants villous-pubescent.
              12. **V. triloba.**
            - Plants obscurely pubescent or glabrate; flowers deep purple; inhabitant of shady uplands.
              11. **V. Lovelliana.**
            - Plants glabrous; flowers pale violet; inhabitant of wet woods.
              6. **V. esculenta.**

Leaves all uncut.

Plants nearly or quite glabrous.

Petals violet-purple; seeds brown.

Petioles glabrous; plants of moist soil.

5. **V. papilionacea.**

Petioles puberulent; plants of dry soils.

7. **V. latiuscula.**

Petals rose-purple; seeds buff.

8. **V. rosacea.**

Petals pale-violet or white; seeds buff.

Vernal leaves narrow, gradually attenuate.

9. **V. missouriensis.**

Vernal leaves broad, subcordate.

10. **V. floridana.**

Plants pubescent.

Plants villous-pubescent, especially on petiole and lower leaf-surface; seeds dark brown.

13. **V. sororia.**

Plants hirsutulous on the upper-leaf surface; elsewhere glabrous; seeds buff.

14. **V. hirsutula.**

2. Cleistogamous flowers on long ascending peduncles, their capsules more or less purplish.

Leaves pubescent beneath and on the petioles.

Sepals and their auricles ciliolate; blades broadly ovate, cordate.

15. **V. septentrionalis.**

Sepals and auricles not ciliolate; blades at flowering time narrowly ovate.

16. **V. novae-angliae.**

Leaves glabrous beneath and on the petioles.

Leaves at vernal flowering narrowly cordate-acuminate; seeds buff.

Auricles of sepals short appressed.

17. **V. affinis.**

Auricles of sepals 2 mm. long, spreading.

18. **V. Langloisii.**

Leaves at vernal flowering subcordate, 3-lobed; seeds bronze.
19. V. **chalcosperma.**

3. Cleistogamous flowers on erect peduncles, their capsules green.
  Leaves ovate to reniform, cordate, glabrous, uniformly crenate-serrate.
    Cleistogamous flowers ovoid; spurred petal villous.
20. V. **nephrophylla.**
    Cleistogamous flowers long and slender; spurred petal glabrous.
21. V. **cucullata.**
  Leaves lobed, or margins sharply incised or toothed towards the cordate or truncate base.
    Spurred petal glabrous, lateral with clavate beard; leaves lobed.
22. V. **viarum.**
    Spurred petal villous at base, the lateral ones with capillary beard.
      Foliage finely pubescent.
        Leaves ovate to orbicular, obtuse.
23. V. **villosa.**
        Leaves ovate-oblong, acute.
24. V. **fimbriatula.**
      Foliage nearly or quite glabrous.
        All leaves uncut.
          Leaves oblong-lanceolate, incised at base.
25. V. **sagittata.**
          Leaves deltoid to broadly ovate, coarsely toothed at base.
26. V. **emarginata.**
        Leaves usually cut.
          Segments 2-3-cleft into linear or oblanceolate lobes; eastern.
27. V. **Brittoniana.**
          Segments 2-cleft, the divisions often 2-4-lobed; western.
28. V. **pedatifida.**

Middle segment uncut, the outer usually 2-4-cleft; southern.

29. **V. septemloba.**

*aa*. Rootstock slender; plants bearing stolons (excepting 30, 32); flowers white, yellow or violet.

*b*. Petals lilac or pale violet.

*c*. Stolons lacking; leaves minutely pubescent on the upper surface; spur large, 7 mm. long.

30. **V. Selkirkii**

*cc*. Stoloniferous; leaves flabrous throughout; spur short, 2 mm. long.

31. **V. palustris.**

*bb*. Petals white, with dark purple lines on the three lower.

*c*. Cleistogamous flowers on prostrate peduncles, their capsules ovoid commonly reddish-brown; plants of cold ravines and low rich woods.

Stolons lacking; lateral petals beardless; leaves reniform.

32. **V. renifolia.**

Stoloniferous.

Lateral petals bearded; seeds obtuse at base.

33. **V. incognita.**

Lateral petals beardless; seeds acute at base.

34. **V. blanda.**

*cc*. Cleistogamous flowers on erect peduncles, their capsules ellipsoid, green; plants of open bogs.

Leaves ovate to oblong.

Leaves ovate cordate.

Leaves toothed; eastern.

35. **V. pallens.**

Leaves entire; western.

36. **V. Macloskeyi.**

Leaves oblong, tapering at base.

37. **V. primulifolia.**

Leaves lanceolate or elliptical.

Leaves elliptical; Pacific coast.

38. **V. occidentalis.**

Leaves lanceolate; eastern.

Leaves 10 to 15 mm. wide.

39. **V. lanceolata.**

Leaves 4-10 mm. wide.

40. **V. vittata.**

*AA*. Caulescent, or with manifest stems.

*a*. Leaves cut or lobed.

*b*. Flowers yellow.

Leaves and sepals ciliate-pubescent.

49. **V. chrysantha.**

Leaves and sepals puberulent.

50. **V. Sheltonii.**

*bb*. Flowers with upper petals dark purple; other petals lighter.

Leaves hirsutulous; lower petals light purple to whitish.

51. **V. Beckwithii.**

Leaves glabrous; lower petals yellowish.

Leaves veined, stipules large.

52. **V. Hallii.**

Leaves 3-ribbed; stipules small.

53. **V. trinervata.**

*aa*. Leaves entire.

*b*. Flower yellow.

First peduncles from the base of the stem.

Flowers on long peduncles much exceeding leaves.

45. **V. pedunculata.**

Flowers on short peduncles.

Leaves oblong-lanceolate, attenuate at base, usually glabrous.

46. **V. Nuttallii.**

Leaves ovate abruptly cuneate, usually pubescent.

Leaves obscurely dentate.

47. **V. praemorsa.**

Leaves 5-7 markedly dentate.

48. **V. purpurea.**

First peduncles from upper half of stem.

Rootstocks filiform; stems spreading or procumbent.

Stems spreading, sometimes rooting at nodes; leaves evergreen.

43. **V. sarmentosa.**

Stems weak, 2-3 leaves; leaves deciduous.

44. **V. biflora.**

Rootstock short, thick, stems erect.

Leaves lobed.

Upper stipules large and foliaceous; Pacific coast.

55. **V. lobata.**

Upper stipules small; eastern.

56. **V. tripartita.**

Leaves uncut.

Nearly glabrous.

Leaves round-cordate; western.

57. **V. glabella.**

Leaves halberd-shaped; eastern.

54. **V. hastata.**

Pubescent.

Sparingly pubescent; root-leaves usually 1-2; stem leaves rarely over 7 cm. wide.

58. **V. eriocarpa.**

Softly pubescent; root-leaves often wanting; stem-leaves broad, often over 7 cm. wide.

59. **V. pubescens.**

*bb.* Flowers not yellow.

*c.* Petals white or lavender.

Petals white.

Underground stolons present.

60. **V. rugulosa.**

Underground stolons lacking.

Sepals subulate, entire.

Upper petals white.

Stems usually 15-35 cm. high.

61. **V. canadensis.**

Stems usually 10-15 cm. high.

62. **V. scopulorum.**

Upper petals purple.

Leaves cordate.

63. **V. ocellata.**

Leaves cuneate.

64. **V. cuneata.**

Sepals oblong-lanceolate, fimbriate.

66. **V. striata.**

Petals lavender.

65. **V. Flettii.**

*cc.* Petals violet or purple.

Spur short; style much enlarged upward into a globose, hollow summit; annual.

75. **V. Rafinesquii.**

Spur long (2-12 mm.); style not capitate; perennials.

Stems stolon-like below ground, low and weak above.

73. **V. Langsdorfii.**

Stems not stolon-like below, high and well developed above.

Spur 7-12 mm. long, style glabrous.

74. **V. rostrata.**

Spur 2-6 mm. long; styles pubescent towards summit.

Stems prostrate, often rooting at the nodes.

Leaves reniform-cordate; southeastern United States.

69. **V. Walteri.**

Leaves oblong-cordate; New Mexico.

70. **V. reptans.**

Stems erect or ascending, not rooting.

The few cauline stipules mainly entire, subradical ones lacineate-dentate.

72. **V. Howellii.**

Stipules from serrate to fimbriate-pinnatifid or pectinate.

Leaves orbicular.

Stipules ovate lanceolate bristly serrate; leaves often 4.5 cm. wide.

67. **V. conspersa.**

Stipules linear, entire except at base; leaves not over 2 cm. wide.

68. **V. labradorica.**

Leaves ovate.

71. **V. adunca.**

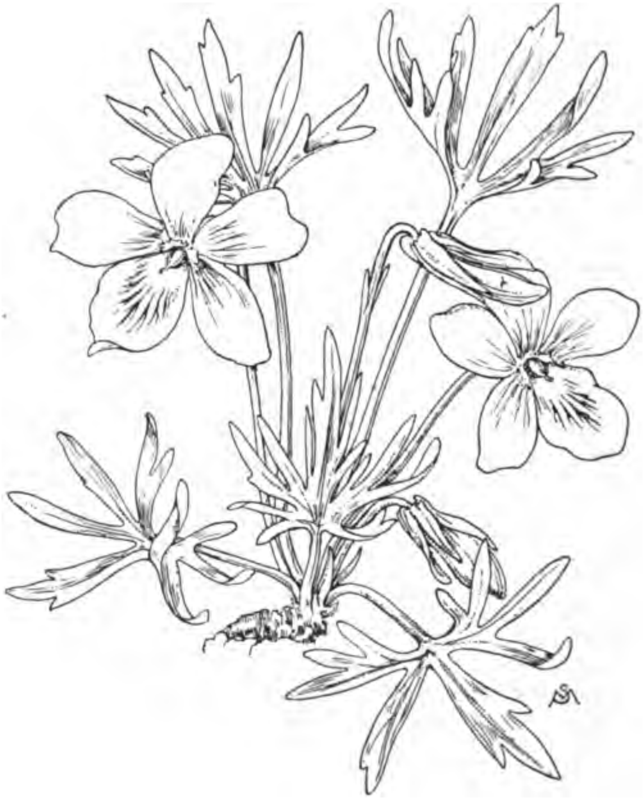
## SPECIES OF NORTH AMERICAN VIOLA NORTH OF MEXICO, ARRANGED ACCORDING TO AFFINITIES

No.
1. V. pedata*
2. V. palmata*
3. V. Egglestonii*
4. V. Stoneana*
5. V. papilionacea*
6. V. esculenta§
7. V. latiuscula*
8. V. rosacea§
9. V. missouriensis*
10. V. floridana§
11. V. Lovelliana§
12. V. triloba*
13. V. sororia*
14. V. hirsutula*
15. V. septentrionalis*
16. V. novae-angliae*
17. V. affinis*
18. V. Langloisii§
19. V. chalcosperma§
20. V. nephrophylla*
21. V. cucullata*
22. V. viarum*
23. V. villosa*
24. V. fimbriatula*
25. V. sagittata*
26. V. emarginata*

No.
27. V. Brittoniana*
28. V. pedatifida*
29. V. septemloba*
30. V. Selkirkii*
31. V. palustris*
32. V. renifolia*
33. V. incognita*
34. V. blanda*
35. V. pallens*
36. V. Macloskeyi†
37. V. primulifolia*
38. V. occidentalis†
39. V. lanceolata*
40. V. vittata§
41. V. rotundifolia*
42. V. orbiculata†
43. V. sarmentosa†
44. V. biflora†
45. V. pedunculata†
46. V. Nuttallii*
47. V. praemorsa†
48. V. purpurea†
49. V. chrysantha†
50. V. Sheltonii†
51. V. Beckwithii†
52. V. Hallii†

No.
53. V. trinervata†
54. V. hastata*
55. V. lobata†
56. V. tripartita§
57. V. glabella†
58. V. eriocarpa*
59. V. pubescens*
60. V. rugulosa*
61. V. canadensis*
62. V. scopulorum*
Boulder, Colo., etc.
63. V. ocellata†
64. V. cuneata†
65. V. Flettii†
66. V. striata*
67. V. conspersa*
68. V. labradorica*
69. V. Walteri*
70. V. reptans§
Robinson Contrib. from Gray Hb.
71. V. adunca*
72. V. Howellii†
73. V. Langsdorfii†
74. V. rostrata*
75. V. Raffinesquii*

The 46 species marked * are in the Atlantic Basin and north of Lat. 37°.
The 9 species marked § are in the Atlantic Basin but only south of Lat. 37°.
The 20 species marked † are only in territory draining into the Pacific.
75 Total.



Species No. 1—**Viola pedata** Curtis not L.

**Viola pedata** L. Sp. Pl. 933. 1753. Species No. 1.

Our color-plate represents the violet of eastern North America that was the first to awaken the admiration of Europeans. The deep purple of the upper petals and the lighter color with dark veins of the three lower ones made it a rival of the pansy. Its gracefully dissected foliage suggested to Linnaeus the name of *pedata,* the Bird-foot Violet. It often assumes, however, a less ornate attire in which all the petals have the lilac-purple of the three lower ones of the type. This was published with a plate in 1789,[1] which unfortunately was taken to represent the real *V. pedata* of Linnaeus, an error that was corrected *only 107 years* later by Greene,[2] who saw the pansy-like form in the vicinity of Washington for the first time in 1896 when entering upon his duties there as Professor of Botany in the Catholic University. The species appears here and in the Alleghanies of western Virginia at its best estate. It was from this vicinity that the oldest collection of the Linnaean material for *V. pedata* was made in 1688. Farther south it recedes from the tide-water plains of the Carolinas, Georgia, and Florida; but in the uplands of the Piedmont region and from western Florida to southwestern Louisiana,[3] large-flowered, concolorous plants are found that match perfectly a water-color of LeConte in which the spread of the corolla is 1.6 inches. This form Greene has published[4] as *V. ampliata. V. redunca* House[5] is another form from the high mountains of South Carolina and Georgia. In short, *V. pedata* is one of our most polymorphic species. Additional names are *V. digitata* Le Conte, var. *bicolor* Pursh, var. *atropurpurea DC., V. flabellifolia* Lodd., var. *flabellata* Don, var. *inornata* Greene, var. *concolor* Theo. Holm.

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[1] Curtis, Bot. Mag. Vol. 3, t. 89. 1789. See line-drawing. Sp. No. 1.

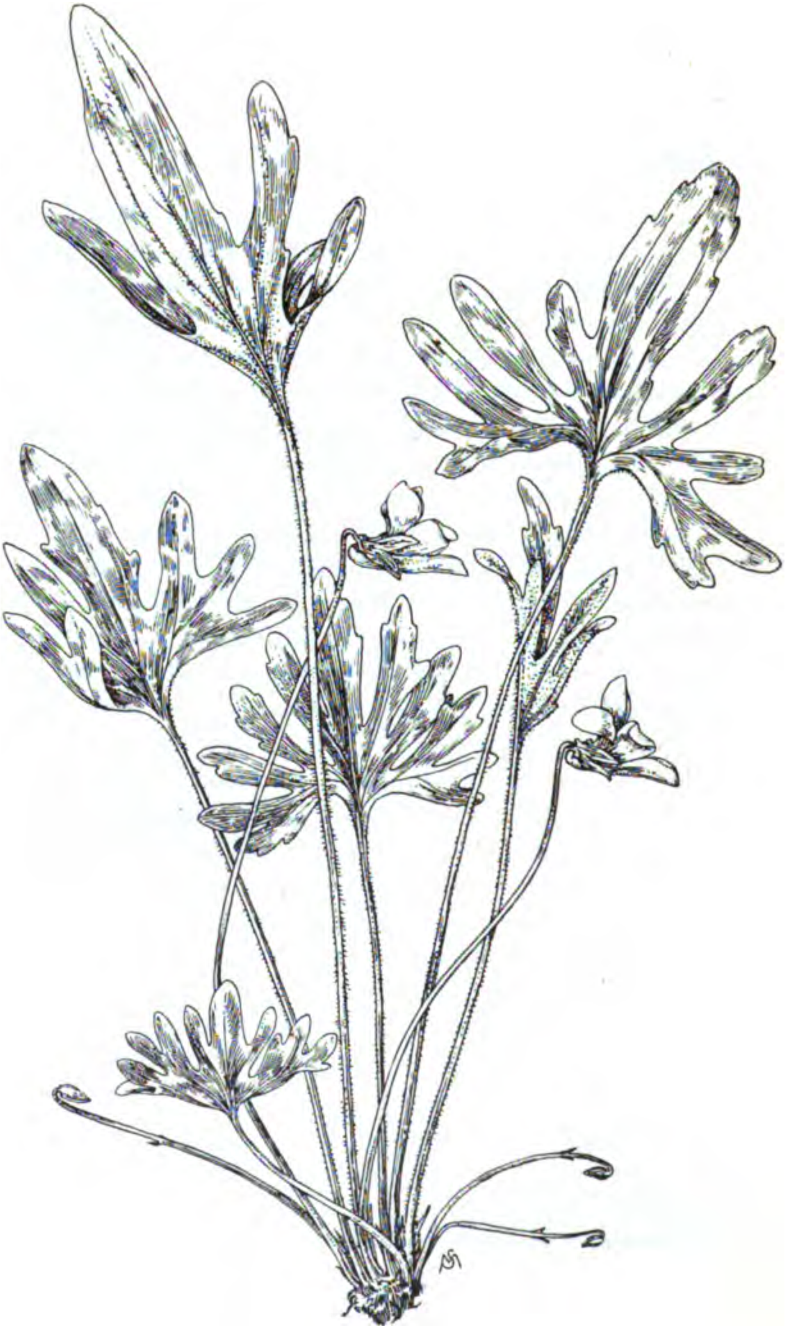
[2] Pitt. 3: 33.

[3] See Brainerd's Distrib. of Violets, No. 117. "Openings in forest of long-leaved pine, Seale, La., March 27, 1910." Cf. Nos. 118 and 119.

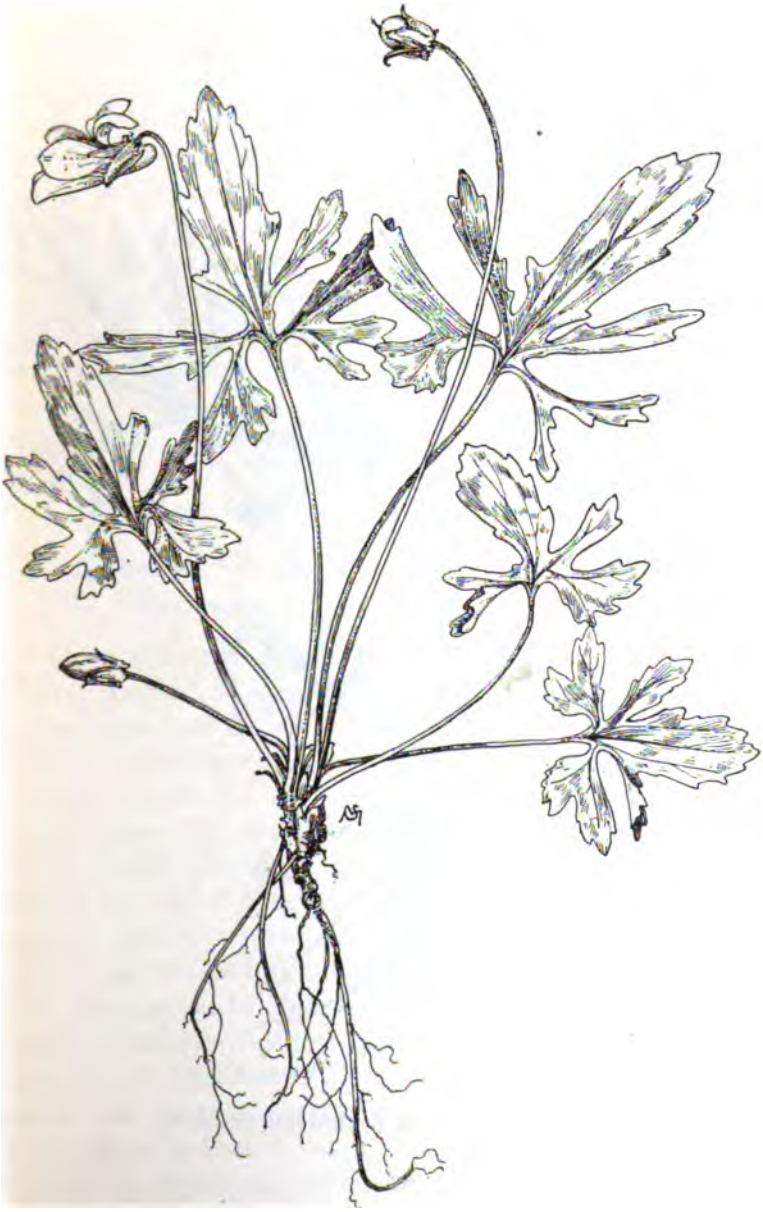
[4] Leaflets 1, 2-3. 1903.

[5] Torreya 6: 171-2. Aug., 1906.

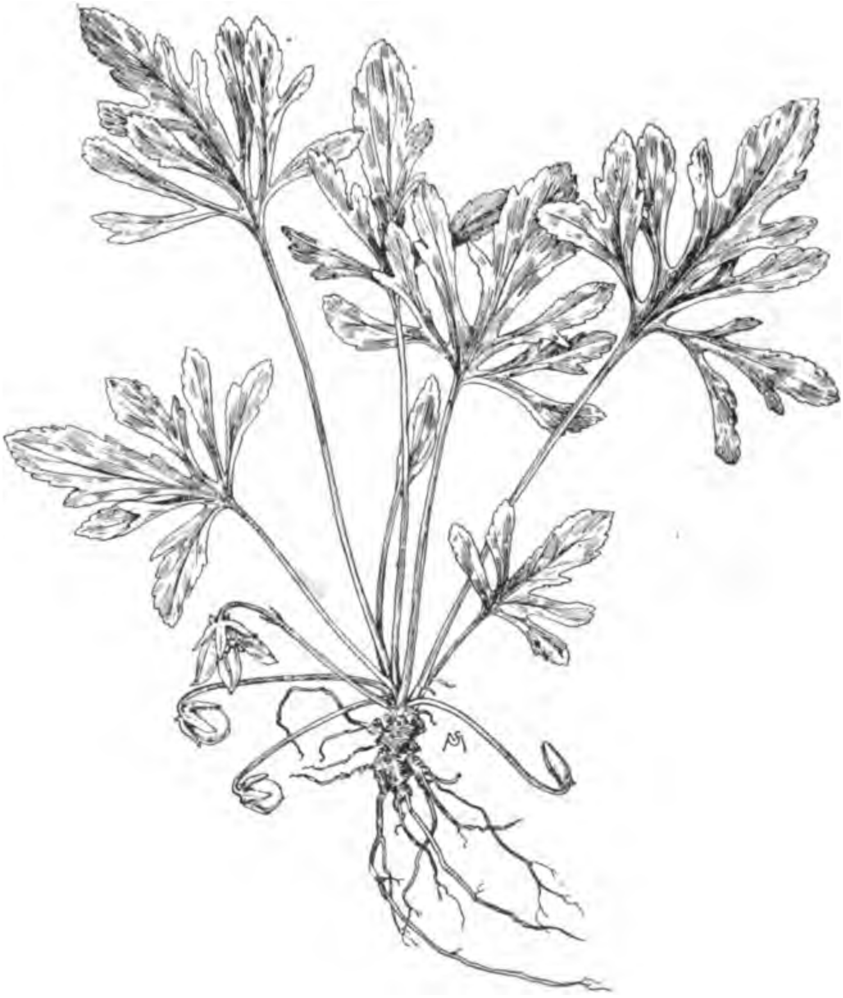
**See also frontispiece color-plate, Species No. 1.**



Species No. 2a—**Viola palmata** L.



**Species No. 2b—Viola palmata L.**



Species No. 3—**Viola Egglestonii Brainerd**

**Viola palmata** L. Sp. Pl. 933. 1753. Species No. 2.

The oldest plate is No. 477, fig. 9 of Plukenet's Amaltheum, of a plant from Florida. This specimen is now in Herbarium Sloane, London. Mr. E. G. Baker reports in Journal of Botany for April, 1898, that it is in part distinctly pubescent, and is well represented by the fig. in Britton's Illustrated Flora, 1st ed., 2: 446. 1897—repeated in 2nd ed., fig. 2924, p. 547. 1913.

Our first line-drawing represents a plant from the most northerly station, Great Barrington, Mass., May 21, 1903, and our second, a plant from near Jacksonville, Fla., March 24, 1909. The northern specimen is more pubescent in accordance with a general law that cool, moist conditions favor pubescence. Otherwise the two plants are much alike, showing no undivided leaves.

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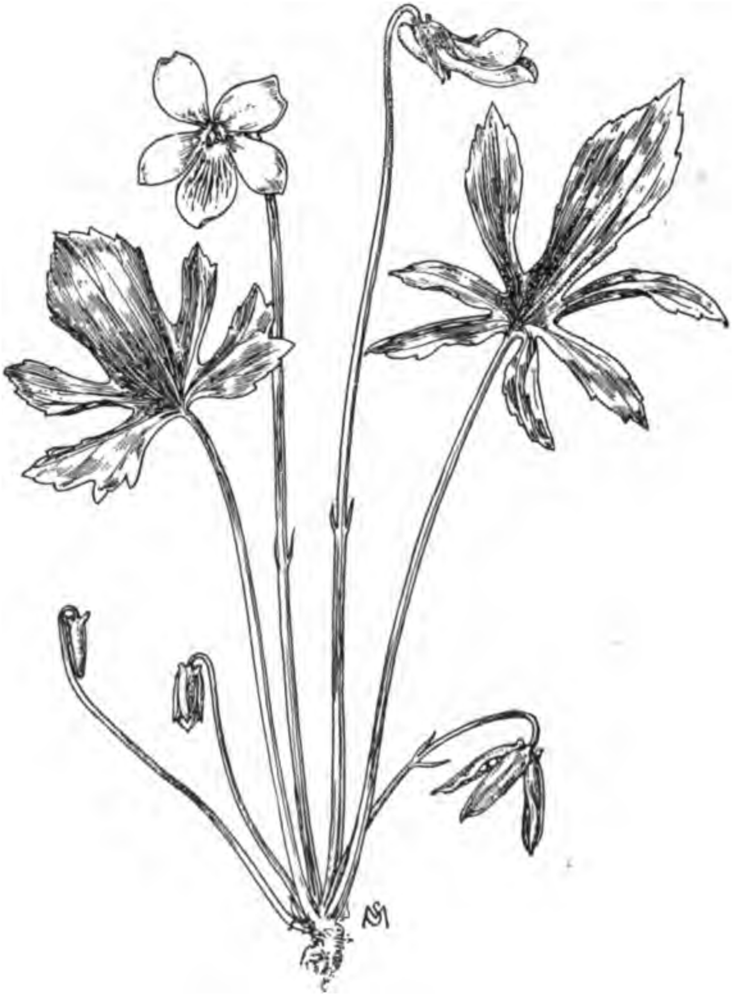
See cuts on pages 16 and 17.

**Viola Egglestonii** Brainerd, Bull. Torr. Cl. 37: 526-7, pl. 34, 35, Nov., 1910. Species No. 3.

This species was collected by Eggleston in the limestone barrens of West Nashville, Tenn., May 26, 1909. Of the four plants sent by him two were published as the type and deposited in the herbarium of the New York Botanical Garden. Our line-drawing is from one of the other two plants. The species, though markedly distinct, is intermediate between *V. palmata* and *V. Stoneana.* Like the latter its range is as yet quite restricted. In the National Museum is a specimen collected by Mr. Williamson near Nashville, Tenn., July, 1897, but named by Pollard *V. viarum.* A still older specimen is in the herbarium of the Missouri Botanical Garden collected May 13, 1881, by Dr. A. Gattinger at La Vergne, Tenn., 15 miles southeast of Nashville. But it is of more interest to find at St. Louis a specimen from Bowling Green, Ky., by Miss Sadie F. Price, April 11, 1899, labelled, "*V. falcata* Greene," for the species is thus entitled to recognition in the Floras of the Northeastern United States.

Both flowering and fruiting specimens are to be seen in my Distribution of Eastern North American Violets, 1910, Nos. 43 and 44.



Species No. 4—**Viola Stoneana** House

**Viola Stoneana** House, Bull. Torr. Cl. 32: 253-4, pl. 16. 1905.
Species No. 4.
*Viola septemloba* Stone, not LeConte, Proc. Acad. Nat. Sci. Phil. 55, p. 678, pl. 35, fig. 2, and pl. 39, fig. 3. 1903.

This species is a near ally of *V. palmata* but less pubescent, and often bearing in early spring one or more small undivided leaves. It is of limited range—moist woodlands New Jersey, eastern Pennsylvania to the vicinity of the District of Columbia. The line-drawing is from a water-color painted from a herbarium specimen transplanted from the type station, Kennett Square, Chester Co., Pa. It is Nos. 162 and 163 of my Distribution of Eastern North American Violets, 1910.

**Viola papilionacea** Pursh, Fl. Am. Sept. 1: 173. 1814. Species No. 5.

We translate the Latin part of Pursh's excellent description as follows: Leaves cordate-deltoid, acute, crenate, somewhat cucullate, nearly glabrous; peduncles the length of the leaves; petals obovate, the three lower bearded below the middle, connivent, the two upper reflexed—"Near Philadelphia, in wet places; flowers blue, elegantly striated and bearded with yellow down." The beard, however, is not yellow, but the throat of the lower petal is a greenish yellow, and against this background the beard might easily appear to be yellow.

The specific name, as Greene observes, is most appropriate, as the shape of the flower resembles that of the garden pea (*not* the Papilio or butterfly of the entomologist), the peculiarly long and narrow keel-petal being concave and boat-shaped. It is, therefore, strange that the name given by Pursh was for 86 years rarely recognized by American botanists until Greene discussed its claims in 1900.[1]

In 1897 the species had appeared in Britton's Illustrated Flora as *V. obliqua* Hill., a vague name accompanied by a still vaguer plate, never quite understood, but applied by violet students, as a convenient makeshift, to some dozen different species. Cf. *V. lactecaerulea* Greene, Proc. Biol. Soc., Wash., 14, p. 70. 1901.

The plant is common in moist fields and grows over a wide tract of the eastern United States—from Maine to Minnesota, thence southward to Georgia and Oklahoma, and did not wholly escape the notice of botanists. LeConte in his monograph of Viola in 1826 recognizes it, but as a variety of *"V. cucullata."* He states that it is abundant on the island of Analostan in the Potomac River opposite Georgetown. One of his water-colors is unquestionably the plant of Pursh. Another synonym is *V. domestica* Bicknell,[2] so called because often found about dwellings and, lastly, *V. pratincola* Greene[3] from the prairies of the Middle West appears not to be specifically distinct.

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[1] Pitt. 4: 140-1. March, 1900.
[2] Appendix Ill. Fl. 3: 519. 1898.
[3] Pitt. 4: 64. July, 1899.
See color-plate, Species No. 5, opposite page 82.

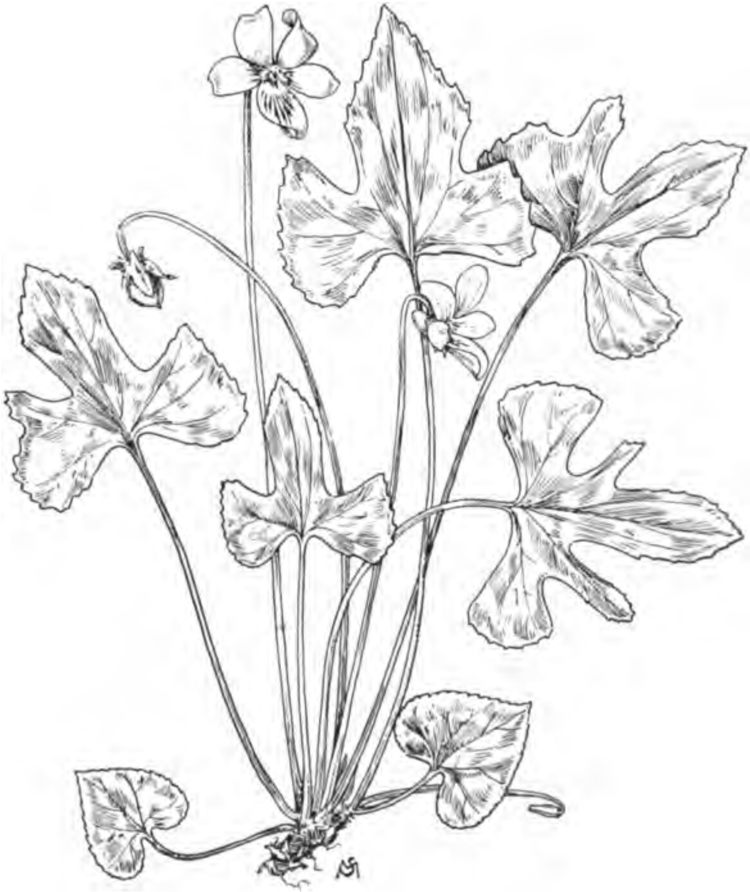
Some account should be given of the beautiful albino forms of this species that occur both in the North and the South.

1. A luxuriant plant has been cultivated for many years in eastern Vermont whose history we have learned through the kindness of Mrs. Laura D. Morgan of Woodstock. Miss Bessie Hewitt of North Pomfret, Vt., when a pupil at Mount Holyoke Seminary in South Hadley, Mass., was the first collector of this albino. Miss Shattuck, the Professor of Botany, determined it to be a variety of "*V. cucullata*" Gray Man., edition 5 (now considered *V. papilionacea*). The living plant was widely distributed and often used for house decoration. In 1909, Mr. Walter Deane of Cambridge, Mass., sent the very same albino from the garden of Mr. Brewster. It is notable for its complete lack of violet pigment in corolla, capsule and seed.

2. Similar albinos have been received from meadows of the Connecticut River at Glastonbury, Conn., growing with the purple-flowered form; and also from New London, Conn.

3. Most interesting of all is an albino from Bowling Green, Ky., *V. Priceana* Pollard. On April 1, 1910, the writer found it growing in the streets of Mena, Ark., where it was known as the "Confederate violet"—the gray petals with purple center suggesting the color of the Confederate uniform. It is a fine garden plant, hardy at the North and still flourishing in the writer's garden.

Our color-plate of typical *V. papilionacea* is based on specimens sent by Greene in 1902 from Washington, D. C., Nos. 103-108, Distribution of 1910.



Species No. 6—**Viola esculenta** Ell.

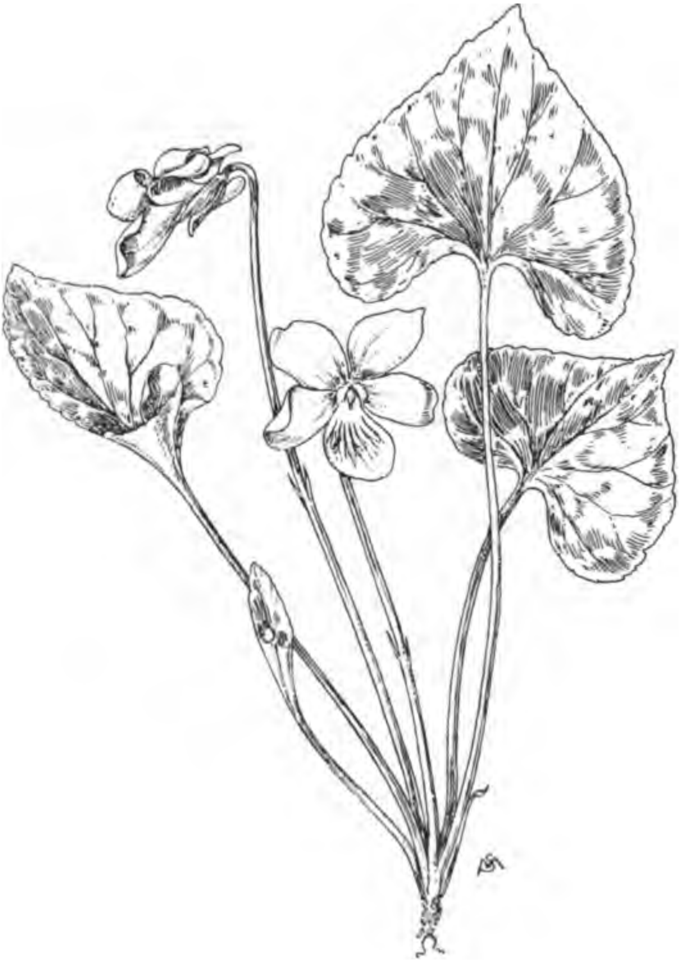
**Viola esculenta** Ell., Bot. S. C. & Ga., 1: 300. 1816. Greene, Pitt. 3: 314. May, 1898. Species No 6.

The type of Elliott's species I have examined in the Elliott herbarium now in the Charleston Museum. The ticket is ambiguously labelled "*Viola esculenta* mihi:" and underneath "Heterophylla Muhl." But when published as above Elliott wrote, "from the circumstance of its being eaten by negroes I had called it *V. esculenta;* it is, however, the *V. heterophylla* of Muhlenberg." This later name was adopted by LeConte, but his water-color, which I have seen, is unmistakably what is now considered *V. esculenta* Ell. Moreover, *V. heterophylla* is invalidated by two earlier uses of the name.

But whatever be the fate of the name, the epithet "heterophyllous" is quite applicable to the species, its leaves being sometimes pedately lobed, cleft or divided, and sometimes merely dentate.

The species is found in river-swamps and on wet borders of slow streams in the coastal plain from South Carolina to Florida, Mobile, Ala., Mississippi City, Miss., seen in National Herbarium, coll. Mohr. It is represented in my Distribution of Eastern North American Violets, 1910, by Nos. 49, 50 and 51.

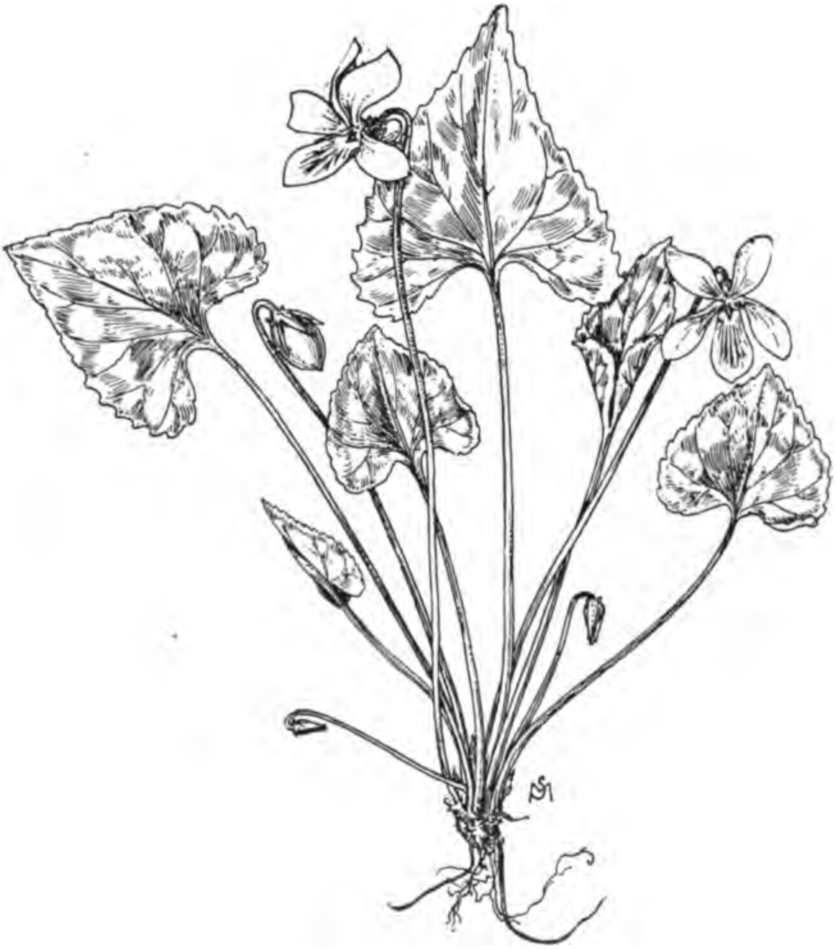
The line-drawing is of a herbarium specimen from Jacksonville, Fla., Brainerd, coll., March 21, 1909.



**Species No. 7—Viola latiuscula Greene**

**Viola latiuscula** Greene, Pitt. 5: 93. Nov., 1902. Species No. 7.

The type was collected by Eggleston in open, shady, well-drained soil on the lower slopes of Twin Mountains, West Rutland, Vt., May 24, and July 15, 1902. At the close of 1903 it had been found in several other stations in western New England and adjacent New York. In 1910 specimens were sent in from western New York and northern Pennsylvania. It is Nos. 75 and 76 of my Distribution of 1910. The line-drawing was made from a water-color painted May 15, 1915, of a herbarium specimen from the type station. Greene's specific name was suggested by its broad, uncut foliage.

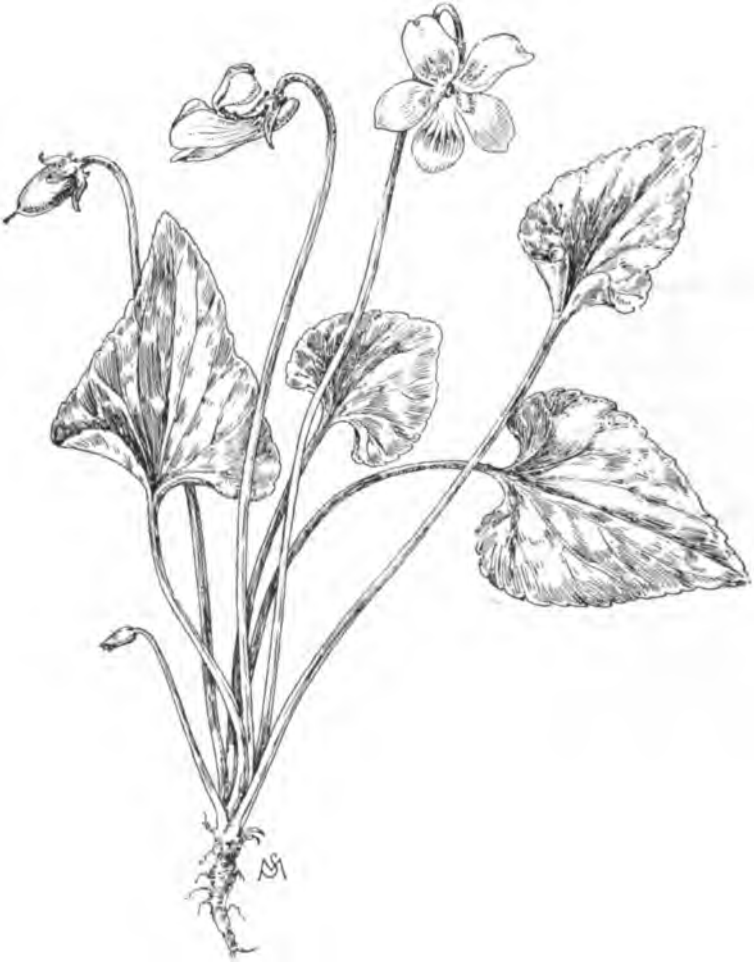


**Species No. 8—Viola rosacea Brainerd**

**Viola rosacea** Brainerd, Bull. Torr. Cl. 37: 525. Nov., 1910. Species No. 8.

This species has uncut, broadly cordate leaves, sparsely hirtellous above; corolla rose-purple about 2 cm. broad, auricles of the three outer sepals short and rounded; seeds buff. Specimens have been collected only at Point Saint Martin near Biloxi on the coast of southern Mississippi and at Crowley, La., and adjacent townships, but may be looked for at intermediate points. Its habitat is dry, open woodland above the bayous.

The line-drawing is based on a herbarium specimen from Crowley, La., Brainerd, coll., March 25, 1910. Specimens from this station may be seen in my Distribution of Eastern North American Violets, 1910, No. 134; and from Biloxi, Miss., Nos. 132 and 133.



Species No. 9—**Viola missouriensis Greene**

**Viola missouriensis** Greene, Pitt. 4: 141. March, 1900. Species No. 9.

Greene's description is detailed and indicates the affinity of the species with *V. papilionacea* and *V. latiuscula,* but differing in having seeds buff instead of brown and in having secondary leaves with more or less concave margins. The species is abundant from central Illinois southwest through eastern Missouri, southeastern Kansas, along the boundary between Oklahoma and Arkansas, and into Texas at least as far south as New Braunfels, Comal County.

The line-drawing is based on a water-color painted May, 1915, from a plant received from B. F. Bush, Courtney, Mo., and grown at Middlebury, Vt. Specimens collected on flood plains of Arkansas River near Muskogee, Okla., March 31, 1908, and on flat land along Flower Creek near Fort Gibson may be seen in my Distribution of Eastern North American Violets, 1910, Nos. 81 and 82.

**Viola floridana** Brainerd, Bull. Torr. Cl. 37: 524. Nov., 1910. Species No. 10.

The species was first collected March 13, 1907, near Jacksonville, Fla., on an embankment for a street railway across a little marsh near Woodlawn Cemetery. In March and April, 1909, the plant was collected at several other stations near Jacksonville, and at widely separated stations in Volusia County—near the famous DeLeon Spring, on the shores of Lake Beresford, on the edge of a tilled field near Lake Munroe and in moist woodland near Deep Creek. In flower and fruit it resembles *V. esculenta,* but its constantly uncut leaves on erect petioles and its habitat in well-drained soil mark it as distinct.

A beautiful specimen, collected at Beaufort, S. C., April 8, 1916, by Mr. Charles F. Batchelder of Cambridge, Mass., was sent the writer, and at once while the flowers were still fresh was painted by Mathews, as shown in our color-plate. A mature capsule has been added from a Florida plant. Nos. 60 and 61, Distribution of 1910.

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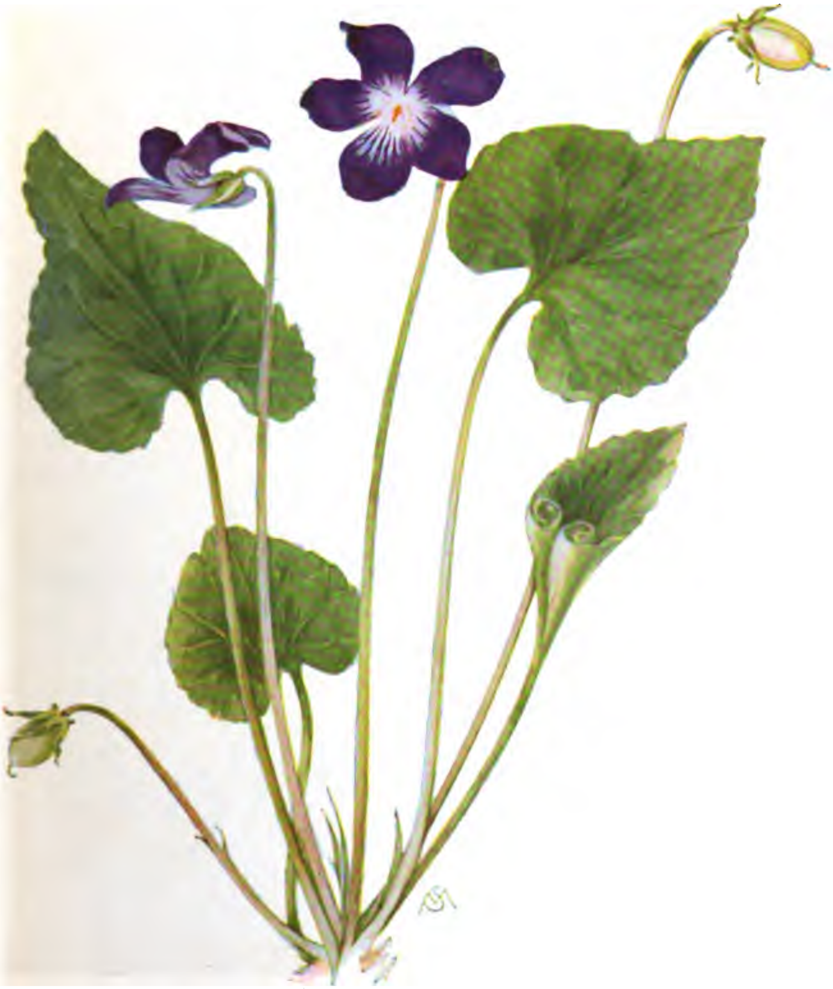
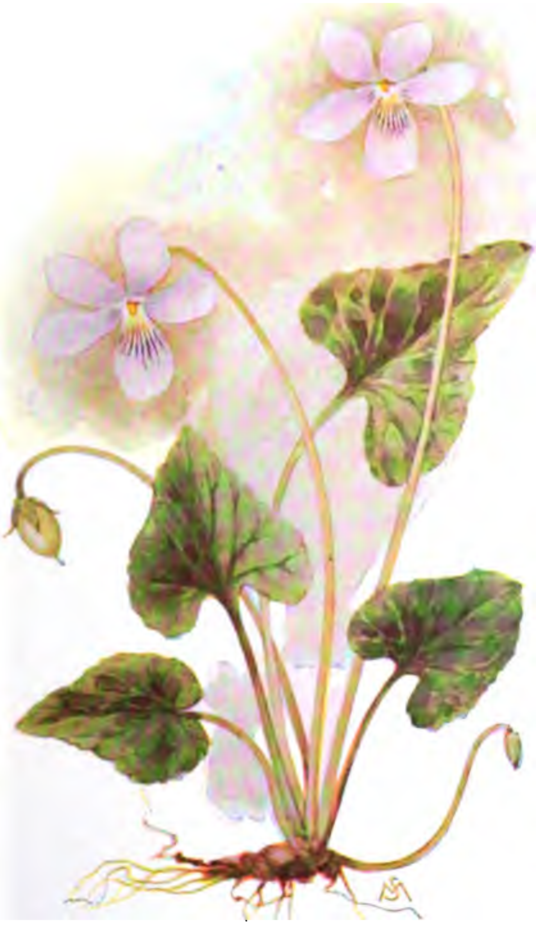
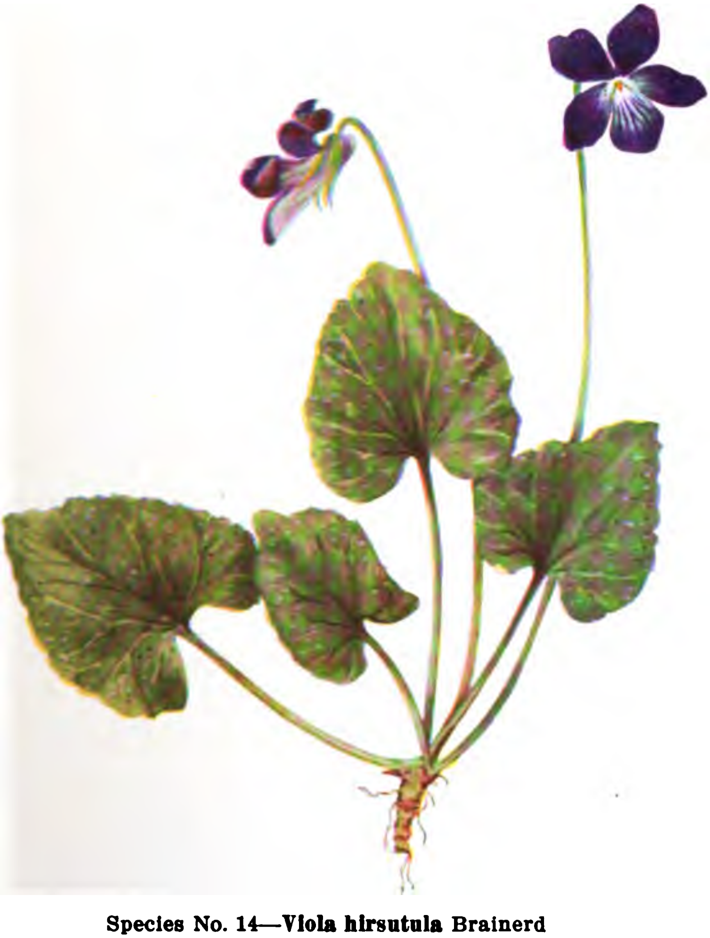
See color-plate, Species No. 10, opposite this page.



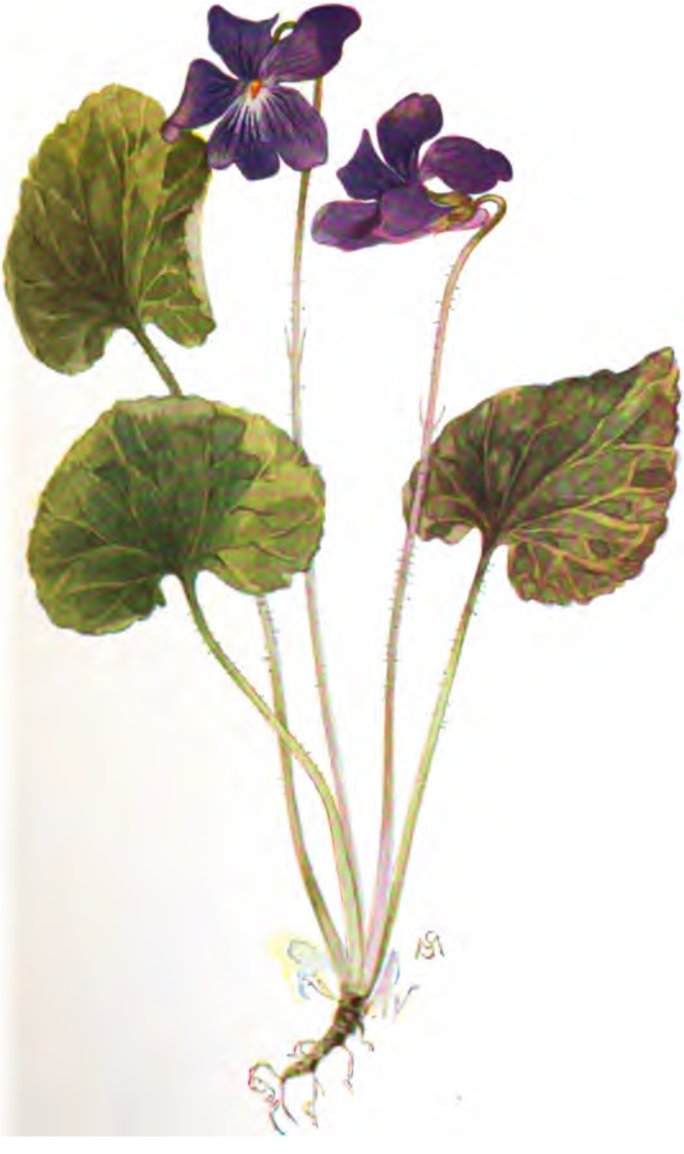
Species No. 5—Viola papilionacea Pursh



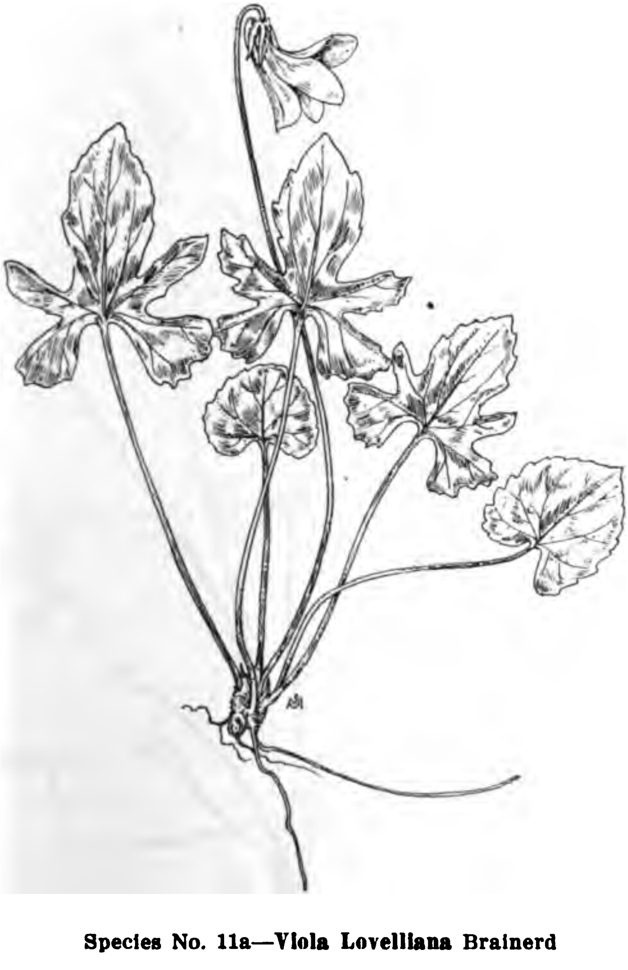
Species No. 10—**Viola floridana** Brainerd



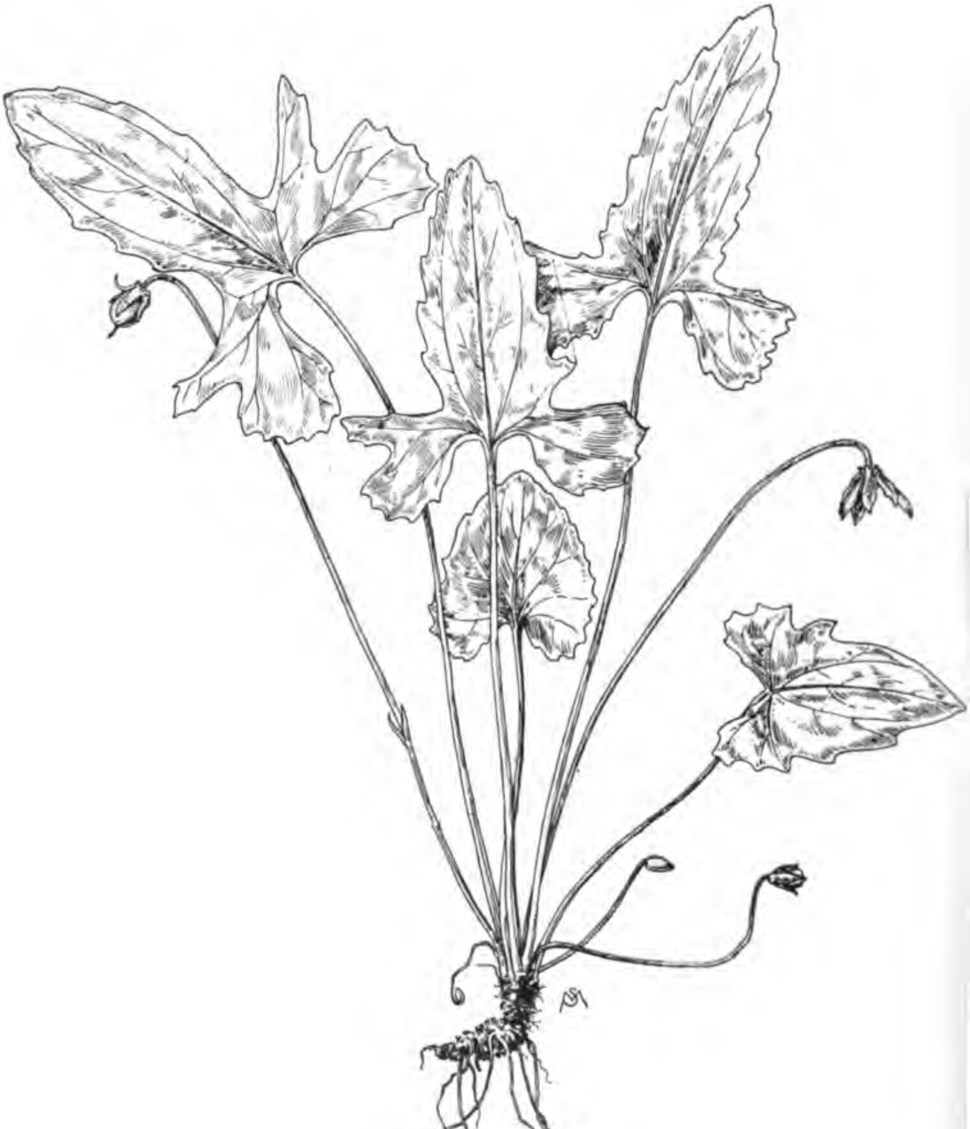
Species No. 14—**Viola hirsutula** Brainerd



**Species No. 15—Viola septentrionalis** Greene



**Species No. 11a—Viola Lovelliana Brainerd**



Species No. 11b—**Viola Lovelliana** Brainerd

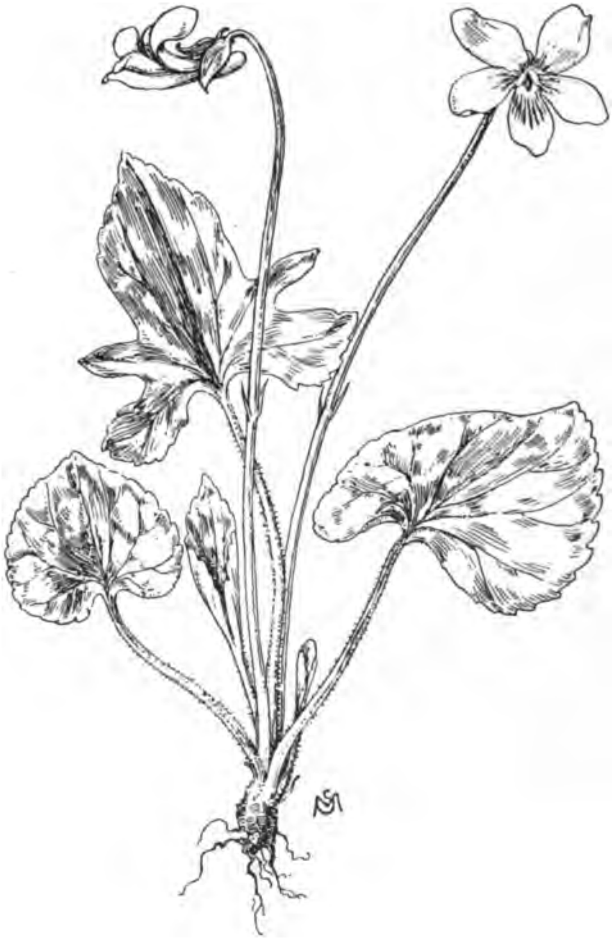
**Viola Lovelliana** Brainerd, Bull. Torr. Cl. 37: 526. Oct., 1910. Species No. 11.

Live plants of this, as an unknown species, were sent me in March, 1906, by Mrs. Phoebe Lovell from Crowley, La., from which late summer specimens were obtained the following August and petaliferous flowers in the spring of 1907. In March, 1908, I visited the station, a recent pine-chopping on loamy clay. As I journeyed northward I collected it in open woodlands near Muskogee, and at Stigler and Eufaula, Okla. In March, 1910, I obtained fine specimens at Mansfield, La., and at Mena, Ark.

The type, in the Bronx Park Herbarium is from Crowley, La., March 25, 1910, and is from a large collection sent out that year as No. 77 of my Distribution of Eastern North American Violets. Nos. 79 and 80 are of specimens respectively from Mansfield, La., and Muskogee, Okla. No. 78 is of seedling plants grown at Middlebury, Vt., in 1909.

The two line-drawings are of herbarium specimens, one in flower and one in fruit, both from Crowley, La., Brainerd, coll., March, 1908.

This violet is most nearly allied to *V. triloba,* both species having some leaves pedately cut and others only dentate.

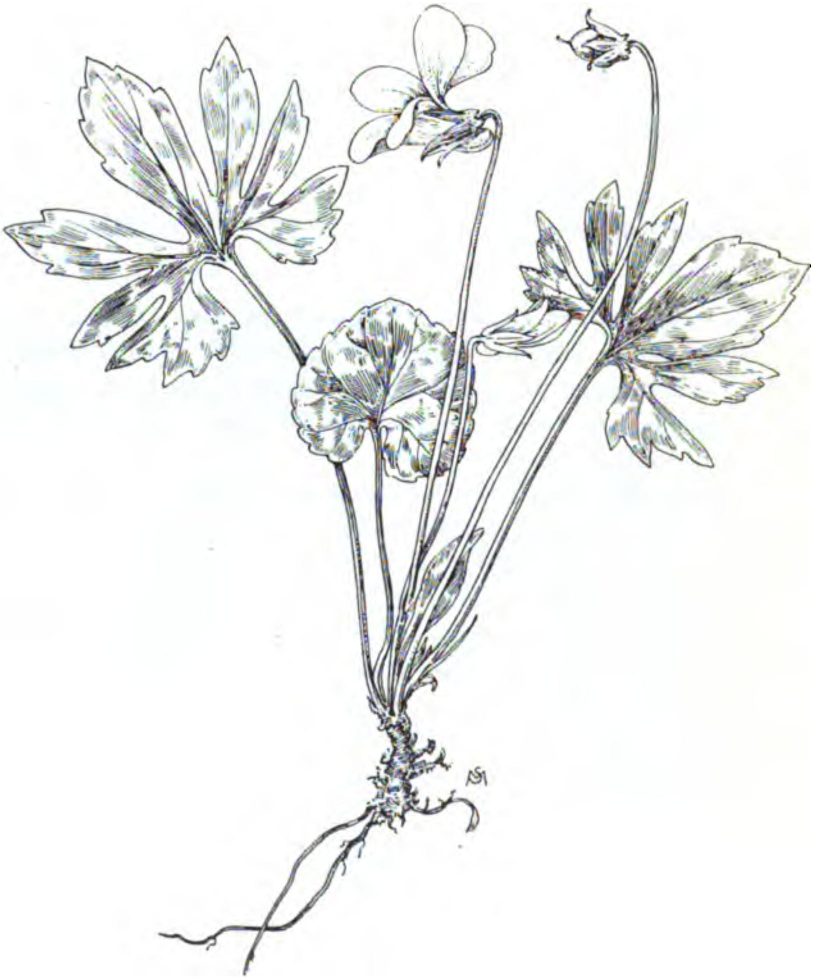


**Species No. 12a—Viola triloba Schwein.**

**Viola triloba** Schwein., Am. Jour. Sci. 5: 57. April, 1822. Species No. 12, a.

The most northern known station is Orwell, Vt. Material from this station is to be seen in Nos. 166, 167 and 168 of my Distribution, 1910. From Vermont the species ranges southward along the Appalachian Mountains to Georgia and central Alabama, and east to the coast as far south as Florida.

In the publication above cited Schweinitz remarks: "With some diffidence I venture to propose this new species." This was apparently due to his having rarely observed it—"twice or thrice," he says, "in different years." LeConte, however, had clearly made out its specific distinctness from both *V. palmata* and *V. sororia,* and in his monograph of *Viola,* October, 1826, published it as *V. congener,* adding "to this I cannot avoid referring *V. triloba* of Schweinitz." But if the two names belong to the same species, the law of priority requires us to adopt the name proposed by Schweinitz.



Species No. 12b—**Viola triloba** Schwein. var. **dilatata** (Ell.) Brainerd

**Viola triloba** Schwein. var. **dilatata** (Ell.) Brainerd, Bull. Torr. Cl. 37: 586-8, pl. 36. Dec., 1910. Species No. 12, b.

*V. palmata* var. *dilatata* Ell. 1817.

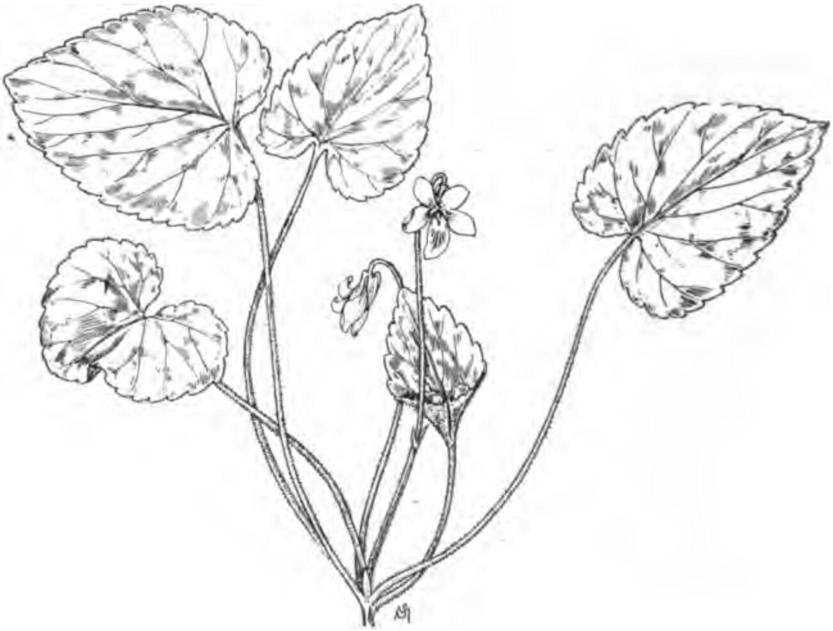
*V. falcata* Greene, Pitt. 4: 3. Jan., 1899.

Little needs to be added to the detailed discussion in Bull. Torr. Cl. of this well marked and widely distributed variety of *V. triloba.*

Specimens of the plant may be found in four numbers of my Distribution of Eastern North American Violets, 1910, viz.:

No. 169, Crowley, La., March 23, 1910;
No. 170, Mansfield, La., March 28, 1910;
No. 171, Mena, Ark., March 31, 1910;
No. 172, Westville, Okla., April 7, 1910.

The line-drawing was based on a specimen in my Distribution of 1910, No. 171, above cited; but specimens at petaliferous flowering are often quite pubescent, and have more narrowly lobed leaves.



**Species No. 13—Viola sororia Willd.**

**Viola sororia** Willd., Enum. 263, pl. 72. 1809. Species No. 13.

Our line-drawing is a copy of plate 72, which well presents the characters of the species in respect to pubescence, shape and serration of leaf. It is strange that for 79 years, from 1818 to 1897, the plant was not known by its correct name. It is a species of wide distribution, occurring in moist meadows, shady ledges and dooryards from western Quebec and New England to Minnesota and south to North Carolina and Oklahoma. See Nos. 158-161, Distribution of 1910.

The confusion caused by Nuttall in his Genera of North American Plants in 1818, who supposed *V. sororia* to be a plant with leaves pubescent only above, described in Rhod. 9: 98, June, 1907, as *V. hirsutula,* is discussed under that species, No. 14. We may, however, call attention to three synonyms published by Greene:

1. *V. cuspidata* Greene, Pitt. 3: 314. May, 1898. The material for this species was from Rock County, Wis. The description points plainly to *V. sororia* Willd.
2. *V. Dicksonii* Greene, Pitt. 4: 65. July, 1899. "A common Canadian Violet," further discussed in Pitt. 5: 63, Nov., 1902, as having baccate fruit, citing specimens from Vermont and elsewhere.
3. *V. nodosa* Greene, Pitt. 4: 296. Sept., 1901. From near Syracuse, N. Y., from H. D. House "related to such species as *V. cuspidata* and *V. Dicksonii.*"

**Viola hirsutula** Brainerd, Rhod. 9: 98. 1907. Species No. 14.

This species is readily distinguished from all other stemless violets by having leaves pubescent above but glabrous beneath. It is common from Bridgeport, Conn., southwest to Washington, western North Carolina, Augusta, Ga., and to Auburn, Lee Co., Ala. See Nos. 64 and 65, Distribution of 1910. For many years it passed as *V. villosa* Walter or as *V. sororia* Willd., owing to errors made by Nuttall in his Genera of North American Plants, 1: 148. 1818.

1. He supposed the plant with leaves pubescent only above to be *V. villosa* Walter (1788).
2. He held *V. sororia* Willd. (1809) to be only a later name for this hirsutulous *pseudo-villosa.*

He thus virtually combined *V. hirsutula, V. sororia* and *V. villosa* into one and the same species.

Against the former error LeConte in 1826 vigorously and justly protested: "When *V. villosa* is misunderstood it is simply by those who have never seen it." His water-color, labelled *V. villosa* Walt., correctly represents that species. But this misconception of *V. villosa* as an hirsutulous plant long survived. In 1898, Greene wrote, "the accepted *V. villosa* is not villous. It is rather stiffly hirsutulous"; and 14 months later he gave a new name (*V. carolina*) to the genuine *V. villosa* of Walter.

LeConte, however, in 1826, adopted Nuttall's second error and held Willdenow's *V. sororia* to be the plant with hirsutulous leaves, as is positively proved by his water-color labelled *"V. sororia."* This error continued in American botany nearly as long as did the other, and in fact led to the disuse of the specific name *"sororia"* for 79 years.

This confusion was probably due in part to a palpable blunder in Willdenow's description, in that he called the spurred petal bearded and the two lateral petals smooth. I say "palpable" blunder, for there is not a known violet in North America that bears such a flower. Willdenow's plate, No. 72[1] was of a plant grown indoors in a pot.

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[1] See line drawing 13.

When grown in the open he says the petioles are a little shorter and the petals broader. He named it *"sororia"*—the sister violet—because of a fancied resemblance to the sweet violet, adding at the close of his formal description "stamens and remaining parts as in *V. odorata.*"

Britton was the first to arrive at a correct conception of Willdenow's *V. sororia,* apparently from a careful study of that author's plate 72,[1] to which Britton's fig. 2489 [2] bears a close resemblance. But he seems to have been still uncertain regarding Walter's *V. villosa.* His fig. 2488, just preceding that of *V. sororia,* and his description are manifestly of the hirsutulous plant. Moreover, Pollard, in the Britton Man., 1901, and in Small's Southern Flora, 1903, presents the same misconception of *V. villosa* Walt. The following summary of the synonymy will help to clear up this confusion:

**V. villosa** Walt., Fl. Carol., p. 219. 1788.
*V. sororia* Nutt., *not* Willd. 1818.
**V. hirsutula** Brainerd, Rhod. 9: 98. 1907.
*V. villosa* Nutt., *not* Walter. 1818.

The most serious phase of this misconception remains to be presented. In 1901, seven years before the publication of *V. hirsutula,* Wilhelm Becker, a violet specialist of Germany, author of "Violae Europaeae" made a distribution of *Violac exsiccatae.* On a printed ticket his No. 36 purports to be

*Viola villosa* Walter, Fl. Carol., p. 219.
Pittonia, Vol. 3, p. 144.
Flora Americ. boreal: Marilandia; copiose ad "Forest Glenn" in collibus arenosis fl. May 7, fr. June 21, 1900.
leg. Th. Holm.

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[1] See line-drawing 13.
[2] Ill. Fl. 2: 448, 1st ed. 1897.

Forest Glen is just north of Washington. The nearest known station for *V. villosa* Walter is Williamsburg, James City Co., Va., 90 miles farther south, and the specimens, a sheet of which is before me, are *Viola hirsutula* Brainerd.

It is surely distressing to learn that now for 20 years *V. hirsutula* has appeared in European herbaria as the *V. villosa* of Thomas Walter —the gifted English botanist, who before the American Revolution settled in South Carolina, studied and cultivated most of the thousand plants published in his Flora Caroliniana (1788), and, when he died a few weeks later at the early age of 48, desired to be buried in his garden among the plants that he so fondly loved.[1]

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[1] See "A Visit to the Grave of Thomas Walter." Bull. Charleston Museum 3, No. 4. April, 1907; and Rhodora 9: 96-8. June, 1907.
See color-plate, Species No. 14, opposite page 38.

**Viola septentrionalis** Greene, Pitt. 3: 334. Sept., 1898. Species No. 15.

In January, 1896, Greene left the University of California to take the chair of Botany in the Catholic University at Washington. He found the region classic ground for violets, where the older American authorities—Pursh, Nuttall, Schweinitz and LeConte—had studied the genus. But there were two northern species which it was Greene's privilege to recognize and describe.

The type of *V. septentrionalis* was collected in rich soil along the border of thickets near Ottawa, Ont., by J. M. Macoun in 1898. A character by which the species may be readily distinguished is the fine and close ciliation of the sepals extending from the lengthened auricles to the very tip of the sepal. See Nos. 154, 155 and 156, Distribution of 1910.

In the Champlain Valley and in the Berkshire Hills of Massachusetts the species abounds on gravelly soil in partial shade; especially in open groves of arbor-vitae on ledges. It is not rare in the Penobscot Valley and along the coast of Maine. The general range of the species is from Newfoundland, Sable Island and Prince Edward Island, west to Ottawa and south through New England to Connecticut and northern Pennsylvania. It has also been found at two stations 20 miles apart on the south line of British Columbia[1] and may be looked for at intermediate points. The following four species proposed by Greene we regard as synonyms of *V. septentrionalis:*

1. *V. Macounii,* Pitt. 3: 335. Sept., 1898.
2: *V. subviscosa,* Pitt. 4. 293, Aylmer, Que. Sept., 1901.
3. *V. Fletcheri,* Pitt. 4: 296, Ottawa, Que. Sept., 1901.
4. *V. nesiotica,* Pitt. 5: 102, Prince Edward Island. Nov., 1902.

Following the last named species is *V. melissaefolia* Greene from Prince Edward Island that proved later to be *V. cucullata* × *septentrionalis,* a violet of remarkable beauty.[2] On the same page he reports having received an aestival specimen of *V. Dicksonii* that bears an underground fruit like a berry—"globose, as large as an ordinary wild gooseberry, absolutely indehiscent." This was later discovered to be a malformation caused by the sting of a gall-fly.

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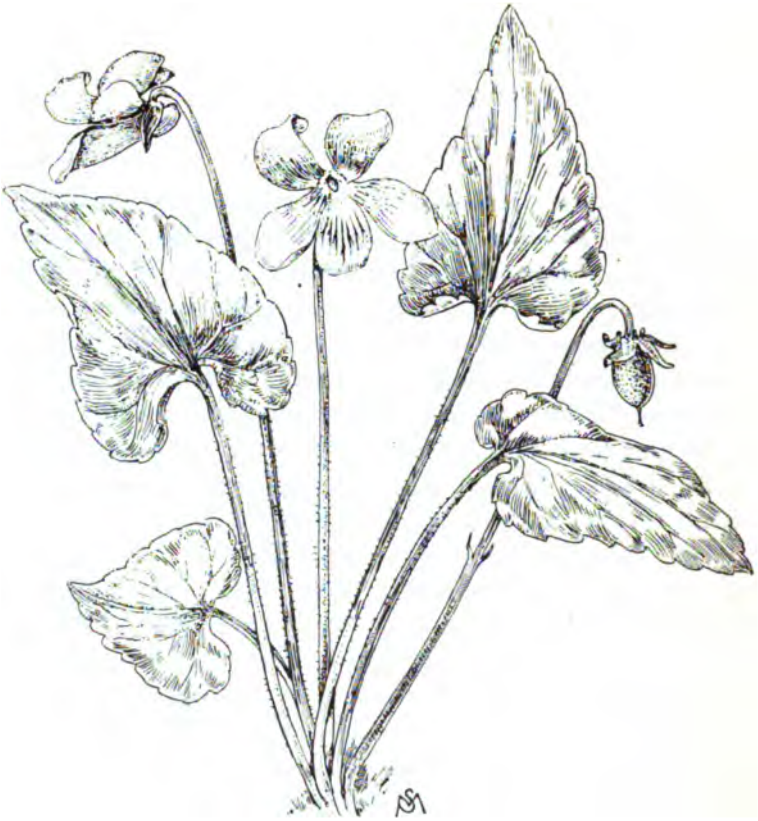
[1] **Rhodora 17: 70. March, 1913.**
[2] **Rhodora 6: 220. Nov., 1904.**
**See color-plate. Species No. 15, opposite page 33.**



Species No. 16—**Viola novae-angliae** House

**Viola novae-angliae** House, Rhod. 6: 226, pl. 59. Nov., 1904. Species No. 16.

The type of *V. novae-angliae* was collected by Fernald (No. 2245) at Fort Kent, Aroostook Co., Me., June 15, 1898. Three days later he collected another specimen at Saint Francis (No. 2244). Both collections were from the headwaters of the Saint John, on the northern boundary of Maine. Pollard determined these specimens as *V. emarginata,* the most northern station for which is southern New York.

In February, 1904, Fernald on sending me duplicates wrote: "I can not believe that the little plant of Fort Kent and Saint Francis has much to do with the southern species. I have always been confident that it represented a thoroughly distinct species. I shall be glad to have you describe the plant if you, too, feel that it is quite distinct." To secure mature specimens he went to the trouble and expense of a journey to Saint Francis, July 7, 1904, and had the live plant reproduced in a water-color, exhibiting the capsules of both petaliferous and cleistogamous flowers.

But while this investigation was in progress House described and figured the species from the flowering specimen sent Pollard, citing in addition to the two specimens from northern Maine, supposed specimens from three other stations: (1) A plant from Orono, Me., oddly enough described and figured in the same number of Rhodora[1] as *V. fimbriatula* × *septentrionalis*. (2) Another hybrid, *V. cucullata* × *fimbriatula*[2] from Bridgeport, Conn., 500 miles southwest of northern Maine. (3) Seedlings of *V. fimbriatula* from the Blue Hills reservation near Boston, Mass.

It is interesting to note what subsequent collections have revealed regarding the range of this near ally of *V. septentrionalis,* the "northern violet." In 1904 I received from Dr. Fletcher of Ottawa, five plants collected at Maple Lake near Parry Sound, Ont., about lat. 45° 20′. In June, 1909, Dr. H. V. Ogden of Milwaukee, Wis., sent live plants from Mercer,[3] Wis., lat. 46° 15′ and the year following other plants from Wild Rose and Saxeville, Wis., 250 miles farther south. Fernald received a specimen from Isle Royal in Lake Superior, Cooper Coll., Aug. 18, 1910, lat. 47°.

To the east of the type station I have received specimens from Saint George, Charlotte Co., N. B., lat. 45° 10′, J. Vroom coll., July and August, 1883, the earliest known collection. And lastly, it was found in lat. 44° 50′ on the rocky banks of the Penobscot, Veazie, Me., by O. W. Knight, June, 1905. See Rhod. 15: 113. June, 1913.

Our line-drawing is based on specimens transplanted from Wisconsin and grown in Middlebury, Vt.

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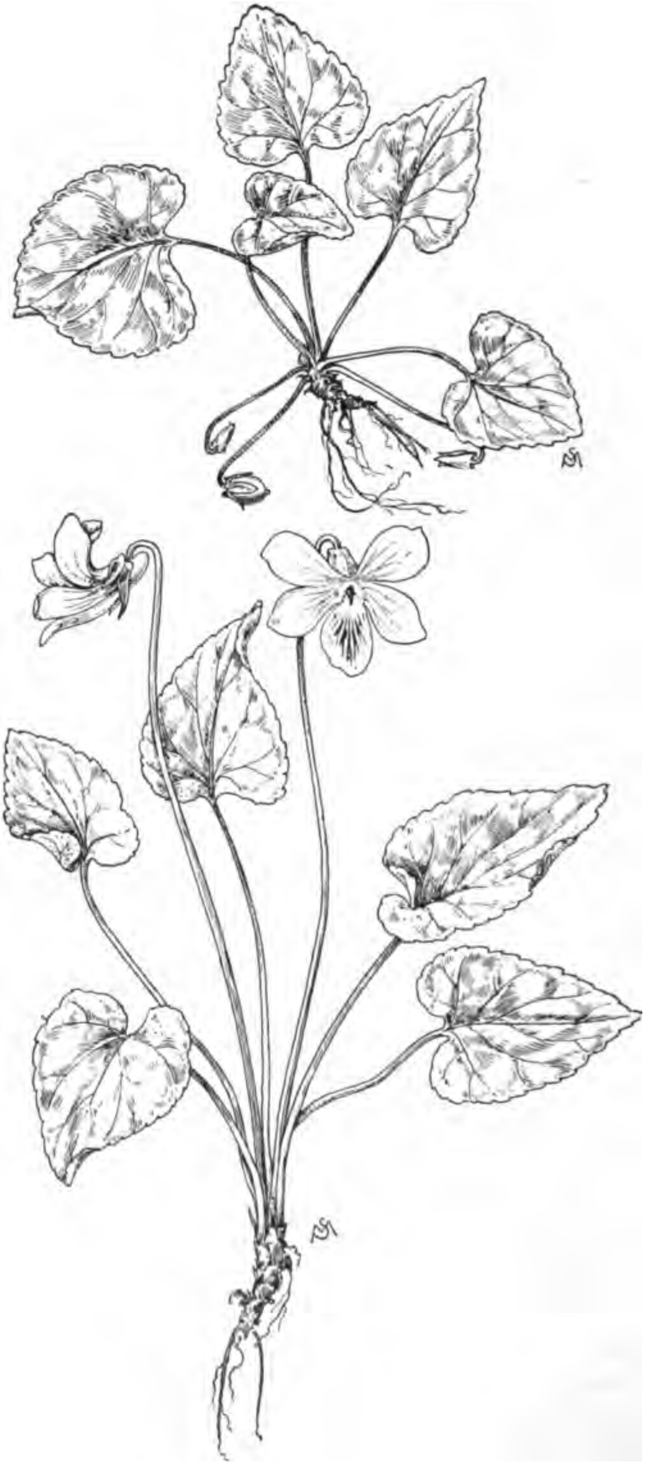
[1] Rhod. 6: 215, pl. 58, fig. a. Nov., 1904.

[2] Rhod. 6: 217-8 and 7: 3.

[3] From seeds of this many plants were raised in 1910. Specimens collected May 15 and August 26, were distributed as No. 89 in my Distribution of Eastern North American Violets, 1910.



**Species No. 17—Viola affinis LeConte**

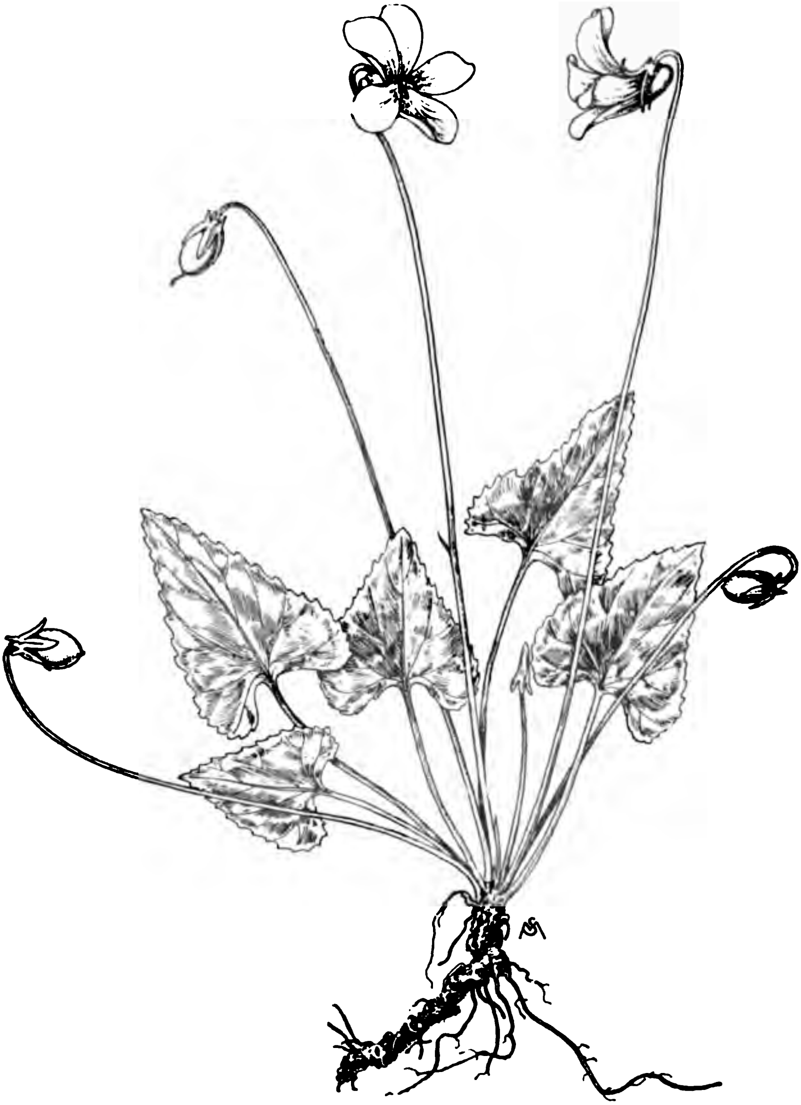
**Viola affinis** LeConte, Ann. N. Y. Lyc. 2: 138. 1826. Species No. 17.
*V. venustula* Greene, Pitt. 3: 335. Sept., 1898.
*V. crenulata* Greene, Pitt. 4: 295. Sept., 1901.

This species was named *"affinis"* because LeConte considered it of near affinity to *V. cucullata.* "I can find," he says, "no distinctive characters except the shorter peduncle and the broader sepals." But his description and his water-color, which was once shown me by Greene, prove that LeConte's species has been correctly understood. In Pitt. 3: 337, Sept., 1898, Greene so determines a specimen collected by James Macoun at Billings' Bridge, Ont. But on the previous page of this same paper Greene published his *V. venustula,* found in a wet meadow near Rideau Hall, Ottawa, Ont., by Macoun, May 23, 1898. I visited this station with Fletcher, September 3, 1904, and was convinced that the plant *"V. affinis,"* common in the District of Columbia, was identical not only with the plant of Billings' Bridge, but also with the *V. venustula* of Rideau Hall, and with plants of frequent occurrence in western Vermont.

In December, 1902, I sent specimens from Middlebury, Vt., to Greene as his *V. venustula* and with some hesitance he consented that Pollard should distribute them under that name.

The habitat of *V. affinis,* as now understood, is moist meadows, low woods and shady borders of streams, and its range is from western New England west to Wisconsin and south to Georgia and Alabama. It is represented by Nos. 1 to 6 in my Distribution of Eastern North American Violets, 1910.

The line-drawing is based on herbarium specimens from western Vermont.

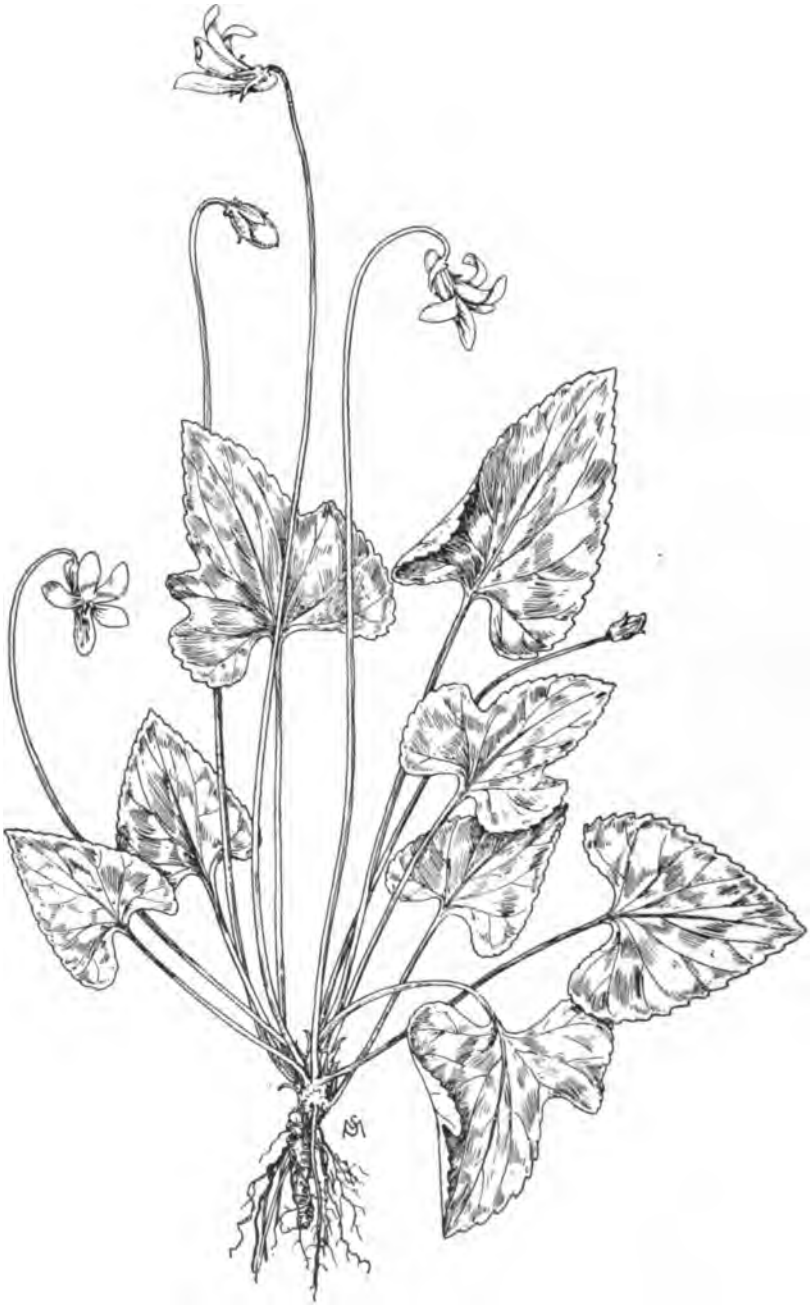


Species No. 18—Viola Langloisii Greene

**Viola Langloisii** Greene, Pitt. 3: 87. June, 1896. Species No. 18.

This species is closely related to *V. affinis* LeConte. A good mark of distinction is found in the lengthened auricles of the sepals in *V. Langloisii* and in that it often exhibits a form with 3-5 pedately lobed leaves. Its habitat is wet, often flooded, borders of bayous, its range from Manatee, Fla., to San Antonio, Tex. The type was collected at Pointe Ci la Hache, near the mouth of the Mississippi River, as I learn from a sheet of the original material kindly presented me by Greene.

The line-drawing is of a herbarium specimen from Crowley, La., Brainerd, coll., March 19, 1908. The species is to be seen in Nos. 72, 73 and 74 of my Distribution of Eastern North American Violets, 1910.



**Species No. 19—*Viola chalcosperma* Brainerd**

**Viola chalcosperma** Brainerd, Bull. Torr. Cl. 37: 523-4. Nov., 1910.
Species No. 19.

This species has been found as yet in only one station—a wet, wooded ravine in Jacksonville, Fla. An expert collector will doubtless find it in similar places in northeastern Florida. The species is well marked by its seeds, which have the color of old bronze, a character which suggested the name of the species. The leaves in early spring when the petaliferous flowers appear are cordate and 3-lobed, the middle lobe ovate and acute, the lateral lobes more or less incised, the later leaves broadly deltoid, twice as long and but slightly lobed, at least when grown in the North; the petals are lilac-purple, the cleistogamous flowers sagittate; the sepals 5 mm. long, the auricles 3-4 mm. long.

My first acquaintance with the species was in the summer of 1907, when Miss A. M. Ryon of New London, Conn., sent me live plants collected the preceding March at Jacksonville by Mrs. E. K. Comstock. Guided by Mrs. Comstock's precise directions I readily found the station on a trip to Florida in March, 1909.

Specimens appear in Nos. 25 and 26 of my Distribution, 1910.

The line-drawing is of a herbarium specimen from Jacksonville, Fla., Brainerd, coll., March 21, 1909.

**Viola nephrophylla** Greene, Pitt. 3: 144-5. 1896. Species No. 20.

The type of this species was collected by Greene "in dry thickets in the valley of the Cimarron River, western Colorado, August 29, 1896." The mounted sheet consists of 14 plants bearing numerous cleistogamous capsules in various stages of development, and occasional reduced petaliferous flowers on pedicles 2-4 cm. long, such as in early autumn are not rarely found in this and other species of *Viola*. For several years afterward the plant was often collected, but vaguely understood. Greene in 1899 examined a specimen from Hull, Que., collected by Macoun, but failing to identify it with the defective Colorado type he gave it another name *V. vagula*.[1] Unlike the Colorado specimen this was in full bloom and described in detail so exactly that I thought it to be probably what Fernald was finding in Quebec and Maine, and others at four different stations in Vermont. To remove all doubt I visited Ottawa, September, 1904, and found *V. vagula* to be identical with the plants from Maine and Vermont, and with the type of *V. nephrophylla* which Greene had kindly sent me for examination.

Probably no North America violet has a wider range—from Newfoundland and Gaspe County, Que., south to Litchfield, Conn., and west along the Great Lakes and the Canadian border to eastern Washington; detouring southward along the Rocky Mountains to Colorado and Utah, and from the eastern slopes of the Cascade Mountains to the northwest border of California. Eggleston collected it also in two counties of Arizona, Cochise and Coconino, and in the mountains of New Mexico south to the middle fork of Gila River, Grant County.

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[1] Pitt. 4: 67. July 7, 1899.

See color-plate, Species No. 20, opposite page 64.

Our color-plate is based upon a plant from the most southerly known station in California. It was collected by Mrs. Viola Brainerd Baird on July 12, 1915, at Lake Donner—a name commemorating the tragic fate of a large family of immigrants, who in 1849 were belated and perished here in the winter snows, often from 15 to 20 feet deep in the passes of the Sierra Nevada. The lake may be seen from the railway train as one is descending the eastern slope of the mountain. See specimens Nos. 81-86 of my Distribution, 1910.

The synonymy may be summed up as follows:

**V. nephrophylla** Greene, Pitt. 3: 144-5. Dec. 16, 1896. S. W. Colorado.

*V. cognata* Greene, Pitt. 3: 145. Dec. 16, 1896. S. Wyoming.

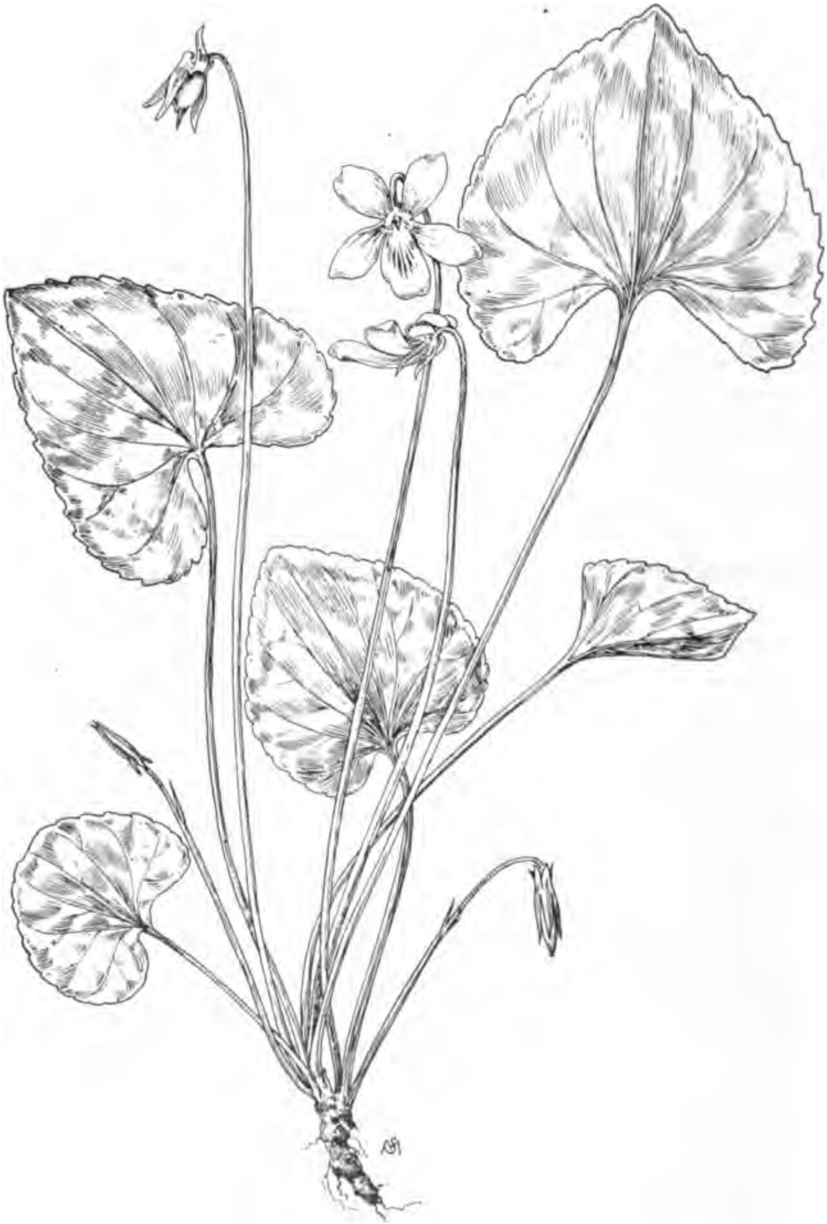
*V. vagula* Greene, Pitt. 4: 67. July 7, 1899. Hull, Que., opposite Ottawa.

*V. Austinae,* Greene, Pitt. 5: 30. Sept. 9, 1902. Plumas County Cal. and Lassen County, Cal. Mrs. Austin, M. S. Baker.

*V. galacifolia* Greene, Pitt. 5: 30. Sept. 9, 1902. Eastern Oregon. Cusick, May 30, 1898.

*V. subjuncta* Greene, Pitt. 5: 31. Sept. 9, 1902. Whitman County, Wash. C. V. Piper, 1898.

*V. arizonica* Greene, Pitt. 5: 33. Sept. 18, 1902. Post Spring, Fort Verde, Ariz. Dr. E. A. Mearns, April, 1888.



Species No. 21—**Viola cucullata** Ait.

**Viola cucullata** Ait., Hort. Kew. 3: 288. 1789. Species No. 21.

The nomenclature of this species was much confused for about a century. There is hardly any decisive character in Aiton's Latin diagnosis except that the lateral petals are longer than the spurred petal. Schweinitz in 1822[1] gives a detailed and exact account of the species, but unfortunately under the name *V. obliqua* Ait. LeConte in 1826[2] correctly described and figured it, but included under it as varieties *V. papilionacea* Pursh, and *V. sororia* Willd. I have before me tracings of his water-colors of these three species. In Gray's last publication on *Viola*[3] he says, "*V. cucullata* Ait. ought to have been referred as an entire-leaved variety to the Linnaean *V. palmata*"; and it so appears in the Synoptical Flora, and in the sixth edition of the Gray Man., p. 79, 1890.

In 1896, Greene took up the study of the eastern violets. In December of that year he described specimens from Ellicott City, Md., collected May 3 and 24, 1896, as *V. cucullata* Ait. probably. In September, 1898, he stated that his former doubts had "been banished." By November, 1902, he had concluded that the bog meadow violet that he had been calling *V. cucullata* was an aggregate of several clearly distinguishable species, and he proceeded to describe and name five new ones.[4] During these six years I was in frequent correspondence and exchange of specimens with him, though not in sympathy with his growing disposition to split species. After 1902 evidence rapidly accumulated regarding the specific and varietal characters, the habitat, and the wide range of *V. cucullata,* and in these matters there has been of late years a general consensus of opinion. A few additional facts, may, however, be stated. The species often bears petaliferous flowers in autumn with notably long auricles. Its cleistogamous flowers are very characteristic—long and slender on erect, often elongate, peduncles. Its habitat is cold bogs and springs, and it is frequently found near the top of our highest mountains. Its range is from Quebec and Ontario to northeastern Georgia; and recently a straggling specimen has been seen in the Bronx Park herbarium collected in swamps, Moark, Ark., B. F. Bush, No. 3755, October 18, 1905.

Our line-drawing is of a plant from the summit of Mount Mansfield just below the hotel, altitude 4,000 feet, July 4, 1906. See specimens No. 32 and No. 33 of my Distribution of Eastern North American Violets, 1910.

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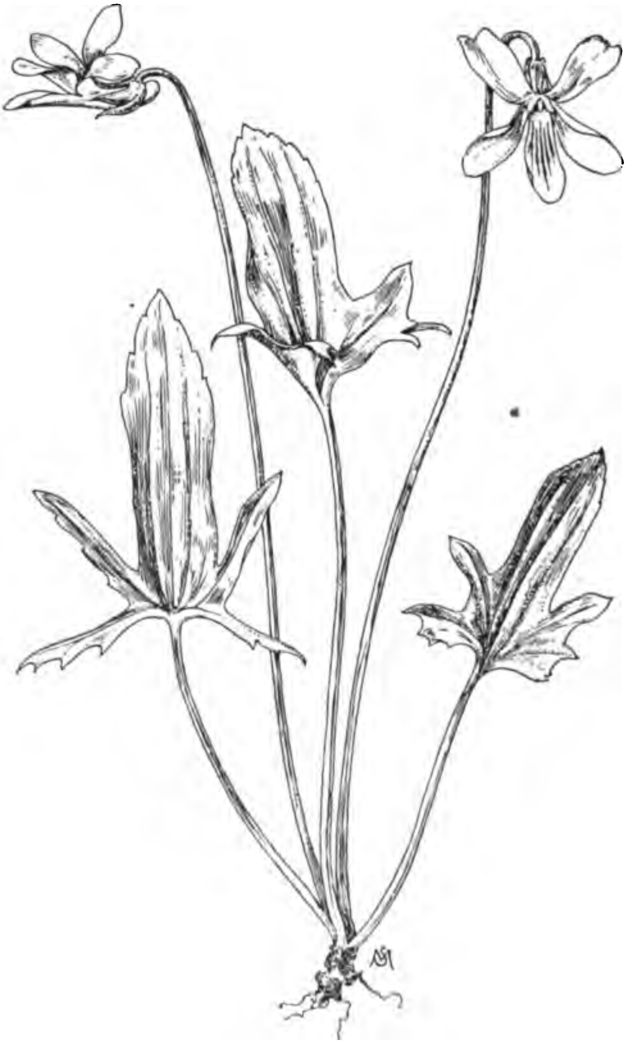
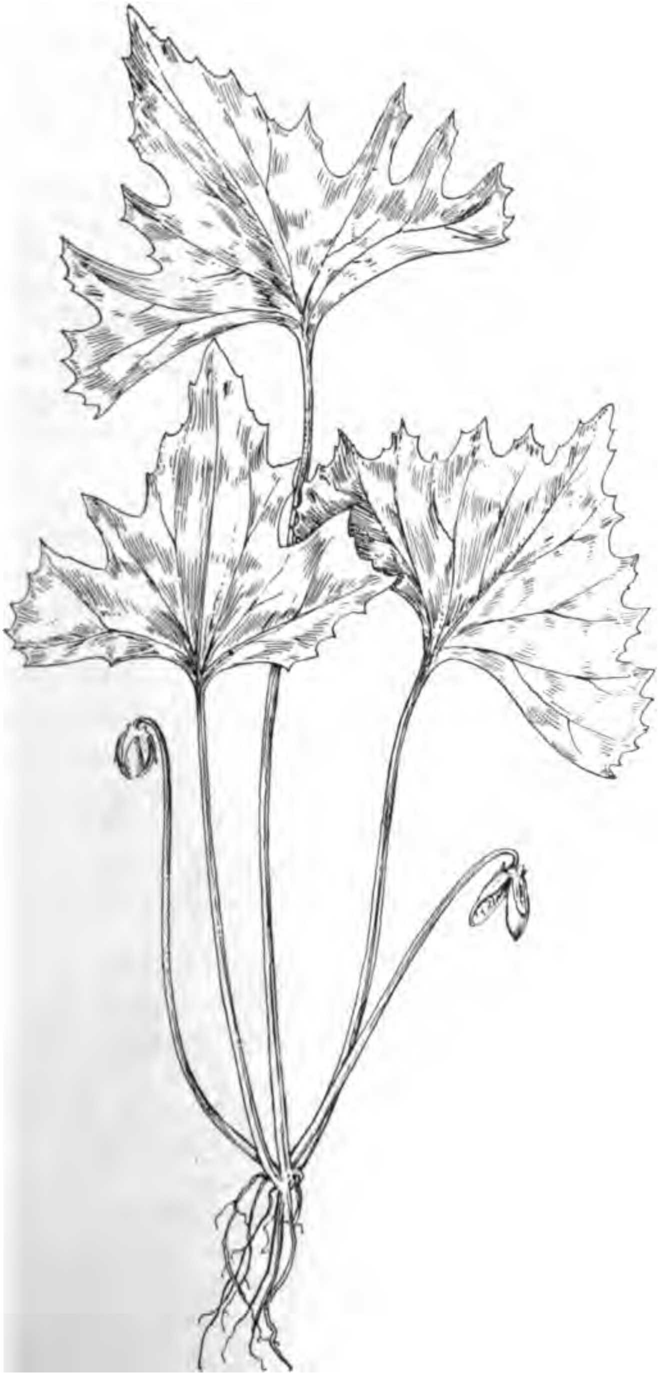
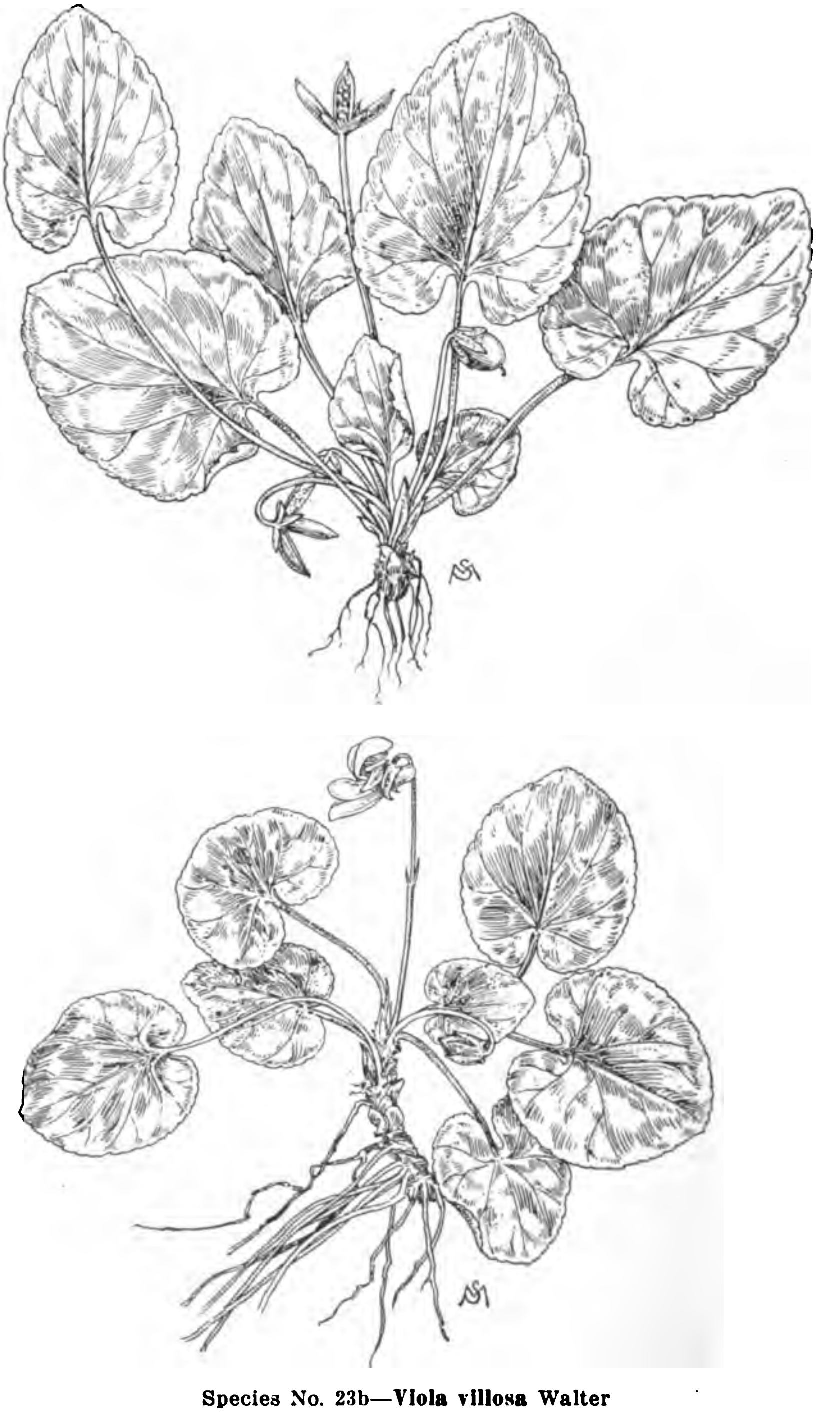
[1] Am. Jour. Sci. 5: 60-1. April. 1822.
[2] Ann. Lyc. N. Y. 2: 137. 1826.
[3] Bot. Gaz. 11: 254. Nov., 1886.
[4] Pitt. 3: 143. Dec., 1896; 3: 336. Sept., 1898; and 5: 96-101. Nov., 1902.



**Species No. 22a—Viola viarum Pollard**



**Species No. 22b—Viola viarum Pollard**



Species No. 23b—**Viola villosa Walter**

**Viola viarum** Pollard, Britton Man., p. 635. 1901. Species No. 22.

The type was collected along railroads in dry soil, St. Louis, Mo., by J. B. S. Norton, July 15, 1899, and specimens of the original collection were distributed from the National Herbarium as No. 32 of North American Violaceae. In August, 1905, the plant was collected at Eagle Rock, Mo., B. F. Bush, No. 3144, and sent me unnamed. From its seeds specimens were grown at Middlebury, Vt., where the plant has since persisted without special care. It was sent out as Nos. 175 and 176 of my Distribution of Violets, 1910. Mr. Bush wrote that the plant was very common along the rocky banks of the White River, which flows southeastwardly for over 100 miles through the Ozark Hills of northern Arkansas. The specimen cited for Oklahoma by Pollard in the Britton Man., page 636, proves to have been *V. papilionacea* × *pedatifida*. The species is reported from Knox County, Ind.

The leaves of *V. viarum* are heterophyllous—some undivided (merely serrate), others pedately 3-7-lobed or parted; the flowers are purplish, the spurred-petal glabrous, the upper pair broader, divergent, emarginate; the seeds dark brown, 2 mm. long.

The line-drawings (pages 58-59) are based on herbarium specimens ex horto grown from the Eagle Rock material. See Nos. 175 and 176, Distribution of 1910.

**Viola villosa** Walter, Fl. Car., p. 219. 1788. Species No. 23.
*V. carolina* Greene, Pitt. 3: 259. Feb., 1908.

Walter's brief description is as follows: "Acaulis, foliis cordato-ovatis villosis, floribus aliquando caeruleis aliquando apetalis."

Greene pronounces this species "no better than a *nomen nudum*. Every one of the descriptive terms that author uses will apply equally well to every other one of our blue-flowered, stemless violets that is not glabrous." But after repeated visits to the tide-water plains of South Carolina where Walter lived, we are confident that no other violet in those flat, sand plains answers to his concise description: stemless, leaves villous cordate-ovate, flowers at times blue, at times apetalous.

Elliott in his Botany of South Carolina and Georgia, p. 297, 1817, is more exact than Walter, noting that the species is very downy rather than villous, the flowers pale-blue and that it grows in dry, sandy soil. Nevertheless, a year later came the misconceptions of Nuttall regarding *V. villosa* and *V. sororia* already discussed under *V. hirsutula*.

The two line-drawings were made from herbarium specimens. The upper showing fruit was collected at Gilmerton, Va., by House, April, 1913; the lower at Auburn, Ala., by Baker, March 18, 1898.

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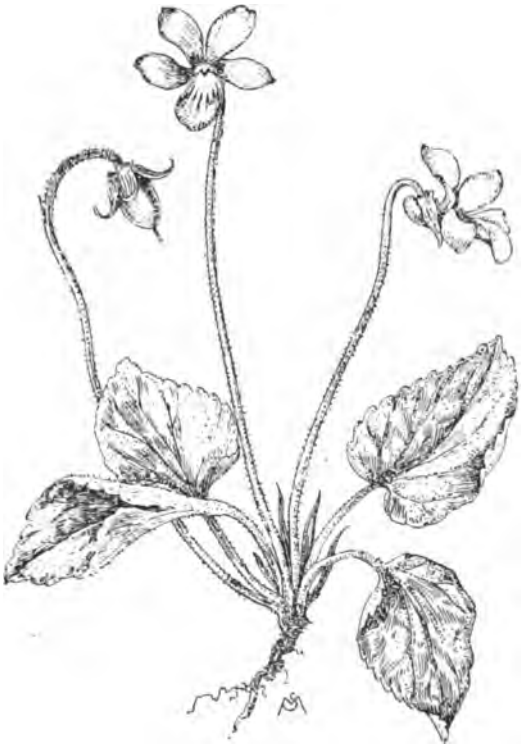
**See also color-plate, Species No. 23, opposite page 64.**



Species No. 24—**Viola fimbriatula** J. E. Smith

**Viola fimbriatula** J. E. Smith, Rees' Cycloped. 37, No. 16. 1817.
Species No. 24.

The confluence of *V. fimbriatula* and *V. sagittata* was set forth in Rhod. 8: 57, pl. 68. March, 1906; and on the following page, between *V. emarginata* and *V. sagittata;* and between *V. emarginata* and *V. fimbriatula.* Observations during the subsequent 15 years have abundantly confirmed these conclusions.

At the same time these aberrant forms ought not in our manuals to divert attention from the normal forms which occur far more frequently in nature. In foliage the three pure species differ as follows:

Leaves pubescent, mostly short-petioled, ovate-oblong, only crenate-serrate at base, *V. fimbriatula.*

Leaves glabrous, rather long-petioled:

(a) Lanceolate at base, often dilated and incised, *V. sagittata.*

(b) Deltoid at base, coarsely dentate, *V. emarginata.*

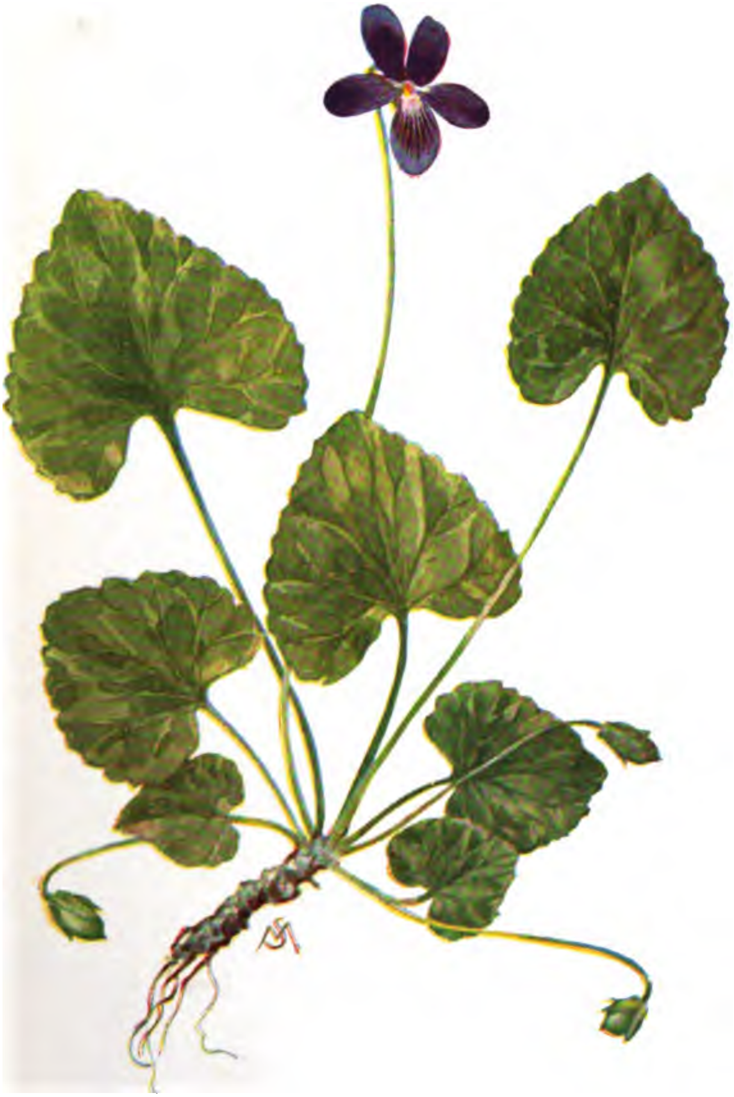
In my Distribution of Eastern North American Violets, 1910, the following numbers illustrate some of the varying forms of the three species under discussion: *V. emarginata* 45-48; *V. fimbriatula* 52-55; *V. sagittata* 139-141.

**Viola sagittata** Ait., Hort. Kew. 3: 287. 1789. Species No. 25.

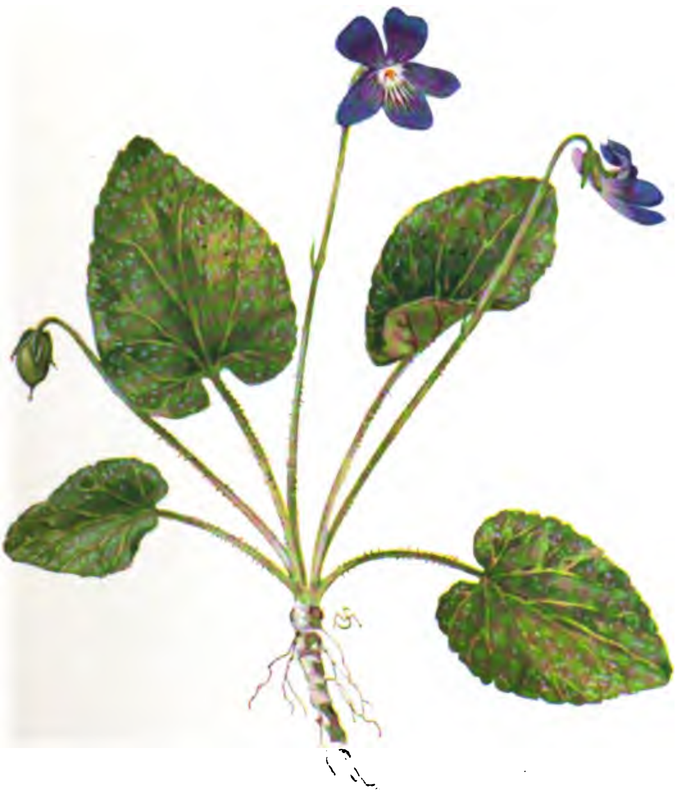
This species has been much confused with its allies *V. emarginata* and *V. fimbriatula* as will appear from the following list of their synonyms.

**V. sagittata** Ait. 1789.
  *V. dentata* Pursh. 1814.
  *V. sagittata* var. *emarginata* Nutt. 1818.
  *V. emarginata* (Nutt.) LeConte. 1826.
**V. fimbriatula** J. E. Smith. 1817.
  *V. sagittata* Pursh, "dry hills" not Aiton. Probably *V. fimbriatula* × *sagittata.*
  *V. primulifolia* Pursh, not L.
  *V. ovata* Nutt. 1818.

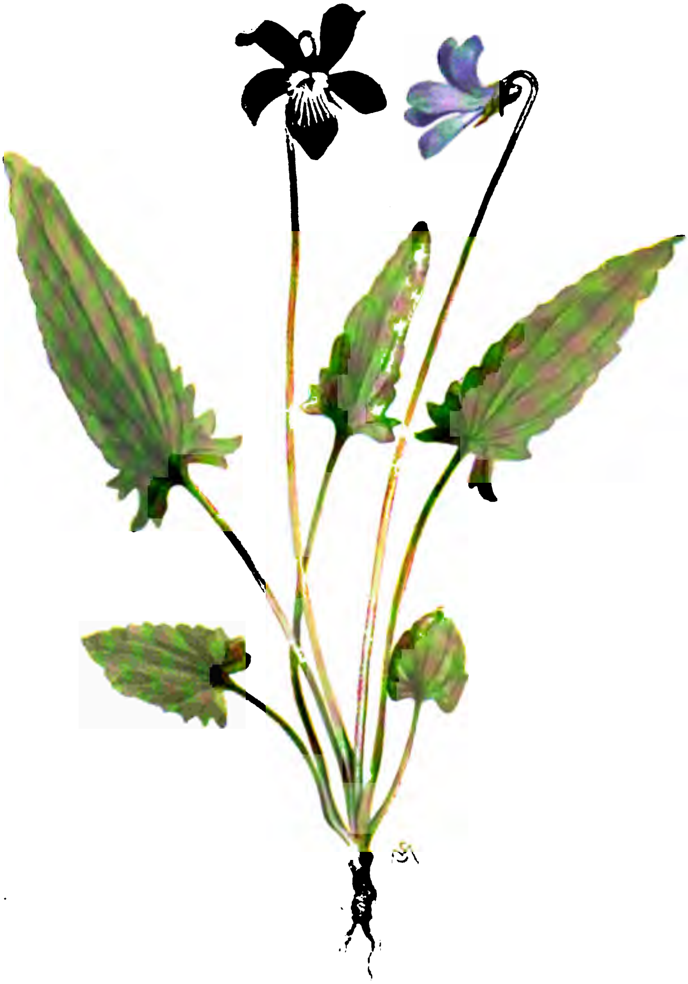
The range of *V. sagittata* is remarkably wide, from eastern Massachusetts south to Louisiana and west into the region of the Great Lakes. The species is also noticeably inconstant as respects pubescence. In the North and West this may be due in part to its interbreeding with *V. fimbriatula.* Philip Dowell reports[1] that "where the two species grow together it is difficult to find the pure species unmixed." But it is also in accord with the general law that low temperature and high humidity favor pubescence, while high temperature and low humidity tend to do the opposite. In other words, under hot, dry, sunny conditions plants are usually less pubescent than under



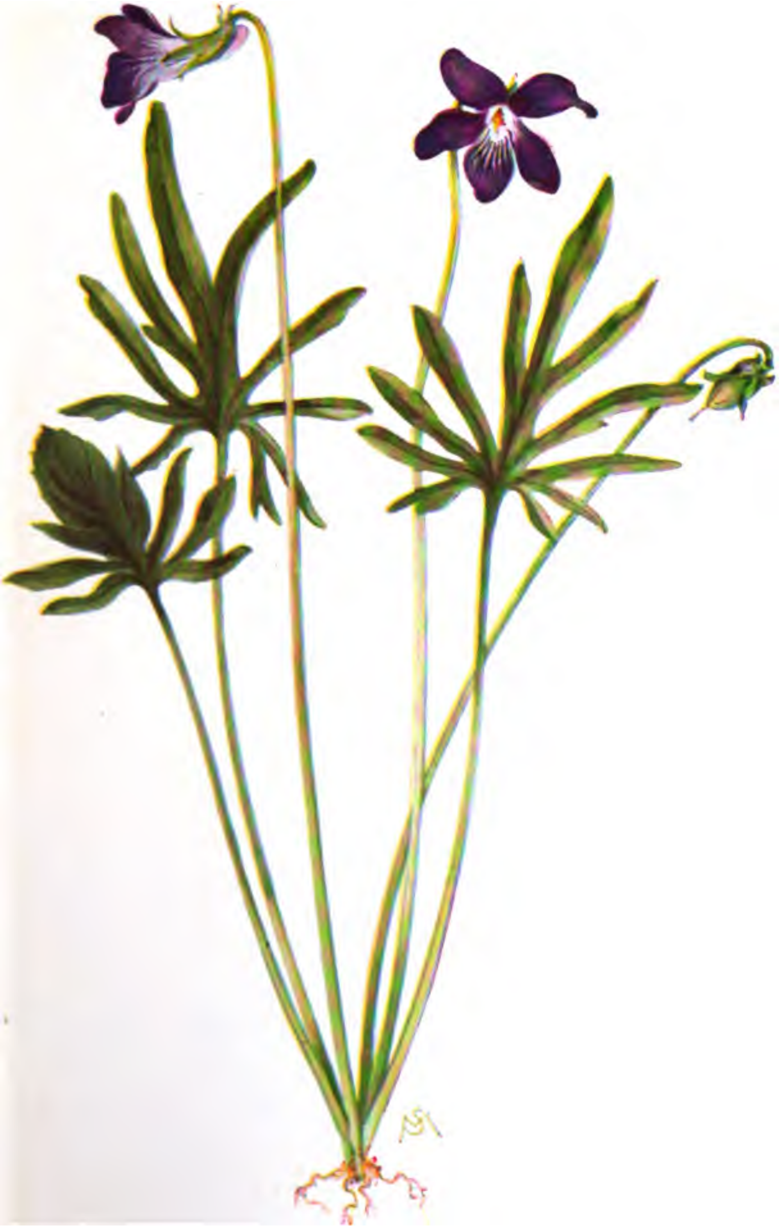
Species No. 20—**Viola nephrophylla** Greene



Species No. 23a—Viola villosa Walter



Species No. 25—Viola sagittata Ait.



Species No. 27—**Viola Brittoniana** Pollard

cool, moist, shady conditions. This is well shown in our two line-drawings of *V. palmata* L., species No. 2, the northern plant from the Berkshire Hills of Massachusetts being markedly villous, the Florida plant almost glabrous. But it is illustrated equally well in *V. sagittata.* In the South the species is habitually glabrous; in the region of the Great Lakes the prevalent form is pubescent and was named *V. subsagittata* by Greene,[2] but the habitat is usually wet meadows or swales or cool shores at the south end of Lake Michigan or Lake Huron.

Gray's final statement regarding *V. sagittata* is significant: "generally well marked as this is, yet it appears to be confluent on one hand into typical *V. palmata,* on other into the var. *cucullata;*"[3]—that is, into a variety of *V. palmata* as var. *cucullata* is regarded in Manual, 6th ed., 1890, probably *V. papilionacea* as now understood. This indicates that he was influenced in his reduction of violet species by his knowledge of the numerous intergrading forms that connect the extreme types of the "*cucullata-sagittata*" group. Whether he considered this due to recent interbreeding or did not, it would support his conception of "var. *cucullata*" as "most polymorphous."[4]

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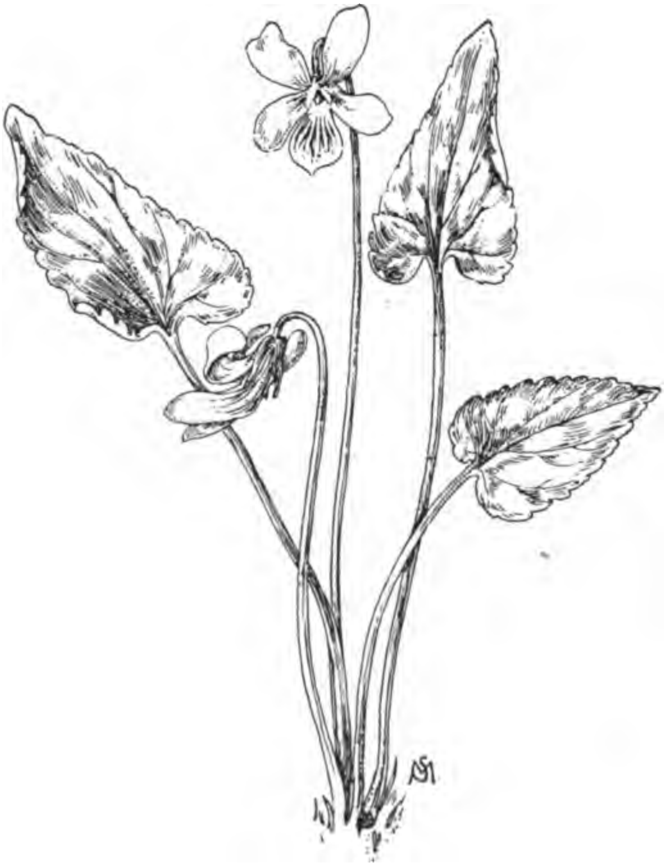
[1] Bull. Torr. Club 37: 175. April, 1910.
[2] Pitt. 3: 315. May, 1898.
[3] Bot. Gaz. 11: 254. Nov., 1886.
[4] Synoptical Fl., p. 196. 1895.
See color-plate, Species No. 25, opposite page 65.



Species No. 26a—**Viola emarginata** (Nutt.) LeConte

**Viola emarginata** (Nutt.) LeConte, Ann. Lyc. N. Y. 2: 142. 1826.
Species No. 26.

The close relationship between this and the last two species and their frequent confluence has been stated under *V. fimbriatula.*

*V. emarginata* was first recognized by Nuttall in his Gen. N. Am. Pl. 1:147, 1818, as a variety of *V. sagittata.* In 1826 Leconte as above cited published it as a species. He remarks: "Found in dry woods from New Jersey to Carolina; it has no resemblance to *V. sagittata,* and may be recognized at first sight by its larger diversiform leaves and larger flowers." On April 1, 1907, Greene showed me Le Conte's water-color of this species, which tallies well with a form that I have collected at many stations in the Carolinas and Oklahoma. This is less deltoid than the form found north of southern Virginia, and the notched petals that suggested Nuttall's original name, "emarginata," are lacking. See 45, 46 and 47 of my Distribution, 1910.

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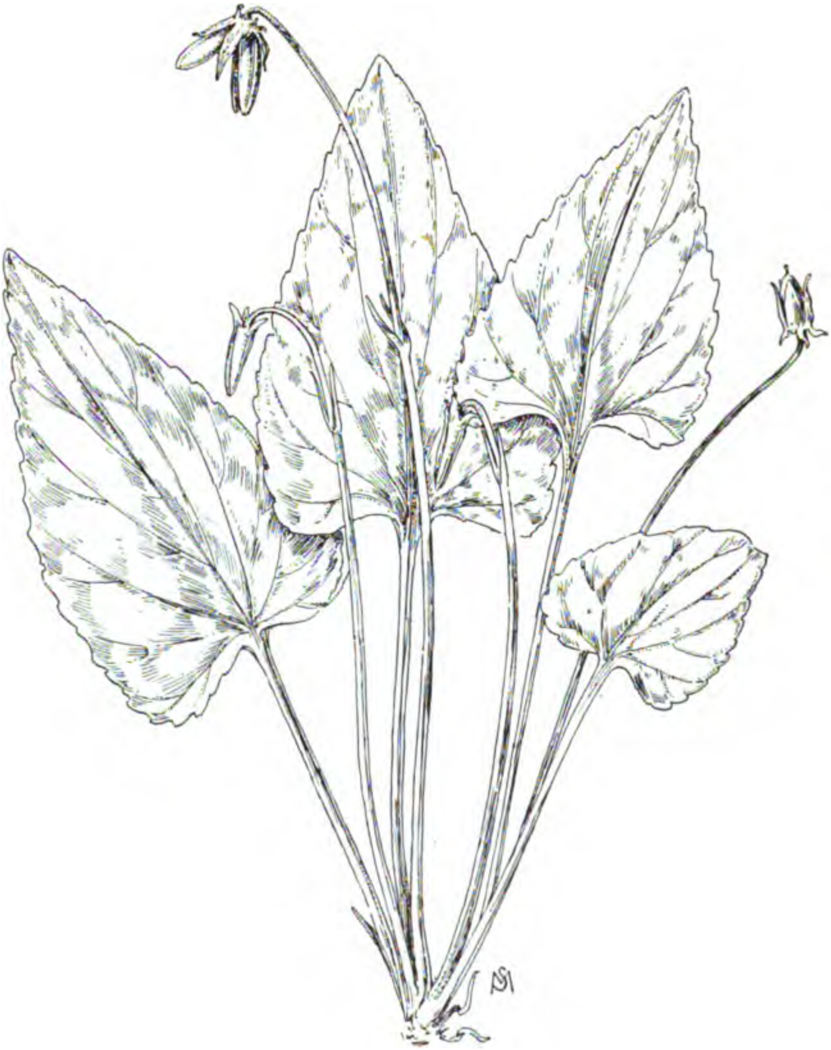
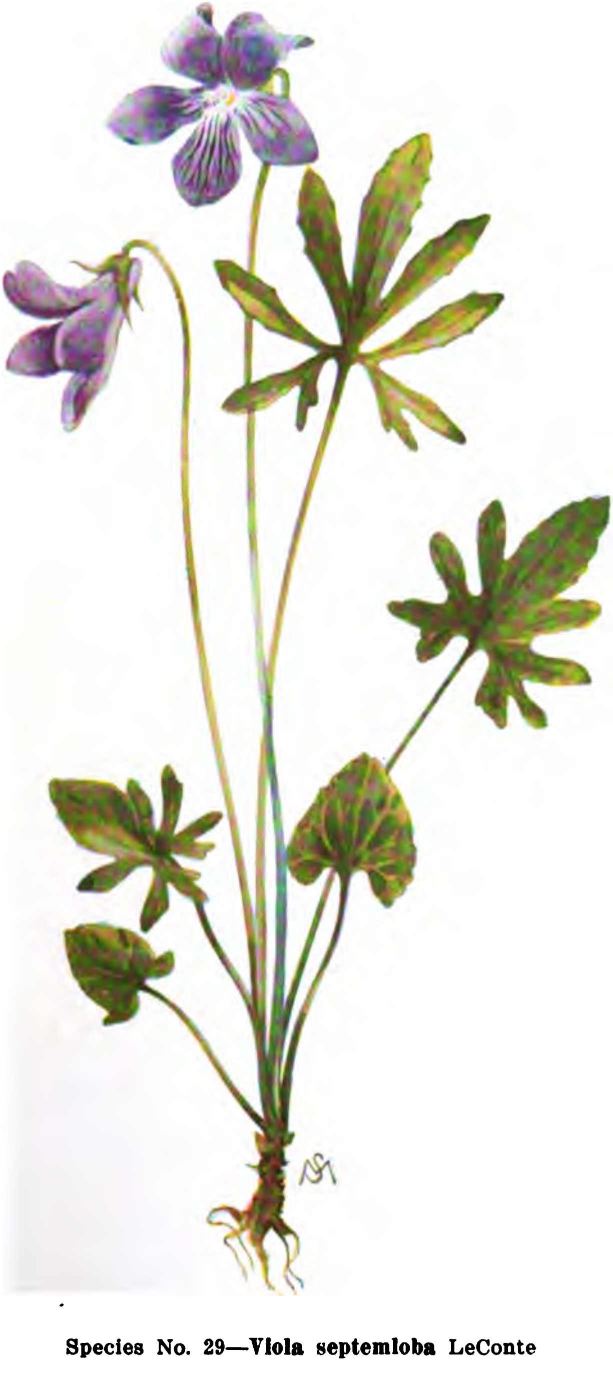
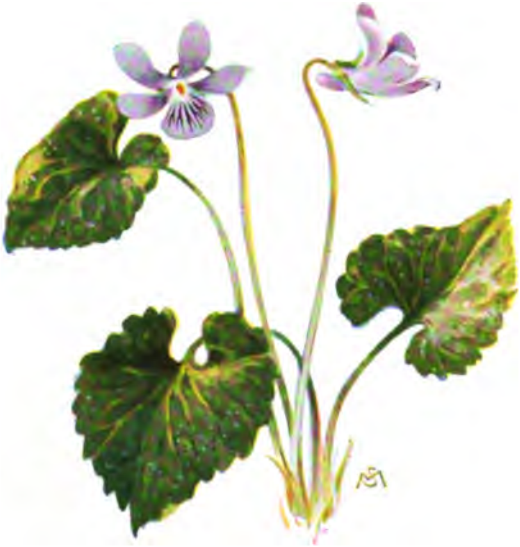
See line-drawing, page 66, based on a plant of the Northeastern United States; and line drawing, page 68, based on a herbarium specimen ex horto, Aug. 30, 1911, transplanted from Oklahoma.



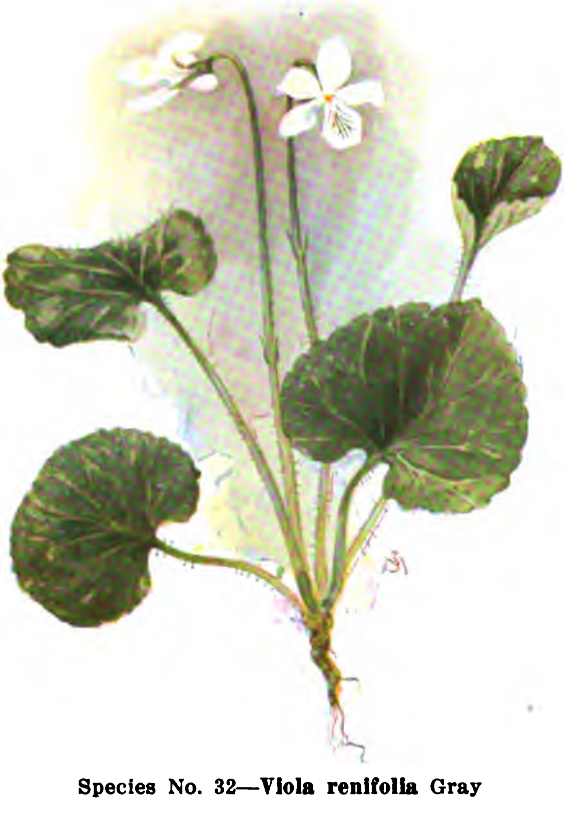
Species No. 26b—**Viola emarginata** (Nutt.) LeConte



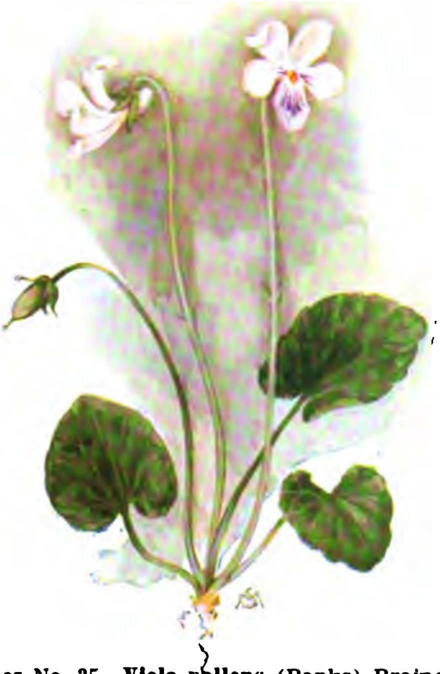
**Species No. 29—Viola septemloba LeConte**



Species No. 30—**Viola Selkirkii** Pursh



**Species No. 32—Viola renifolia Gray**



**Species No. 35—Viola pallens (Banks) Brainerd**

**Viola Brittoniana** Pollard, Bot. Gaz. 26: 332. 1898. Species No. 27.

This species was first recognized by Britton and published in the Torrey Bulletin 24: 92, 1897, and about the same time in the Britton's Ill. Flora 2: 446 as *V. atlantica.* It was soon discovered that the name had been used for a European species by Pomel in 1874; and Pollard had the pleasure of publishing the American plant as *V. Brittoniana.* We present a color-plate of this attractive species, found in peaty or moist, sandy soil along the coast from Maine to Virginia. See also No. 17 of my Distribution, 1910.

Associated with this species is usually found an allied plant appropriately named *"pectinata"* by Mr. Bicknell[1] from the long, narrow, comb-like incisions of the leaf-blade. In all other characters—in flower and fruit, in fertility, in size and color of seeds and in rootstock—the plant is identical with typical *V. Brittoniana.*[2] It appears to be a case of dimorphism not infrequent in *Viola* and is discussed in our account of *V. hastata* Mich., species No. 54.

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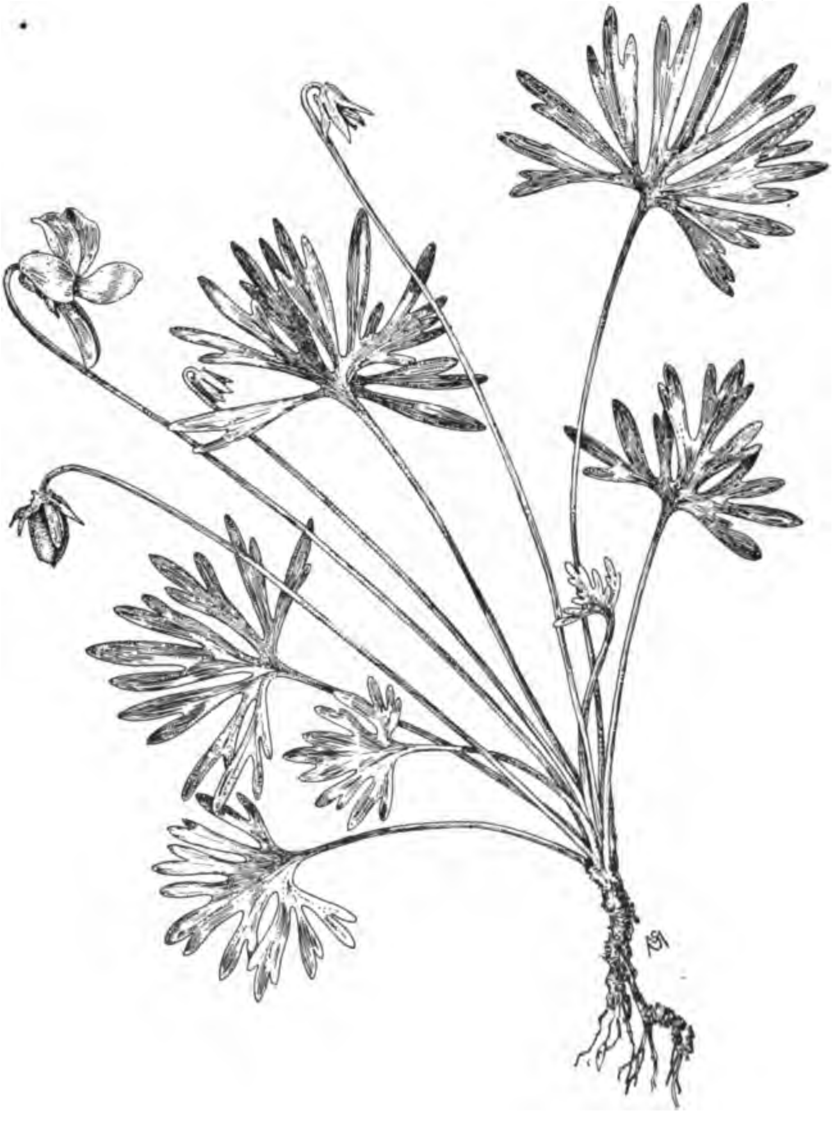
[1] Torreya 4: 129. 1904.

[2] See Rhod. 8: 59, pl. 69. March, 1906; where for *V. scptemloba* read *V. Brittoniana.* See No. 115 Brainerd's Distrib. of Viola, 1910.

See color-plate, Species No. 27, opposite page 65.



**Species No. 28—Viola pedatifida Don**

**Viola pedatifida** Don, General System, Gard. Dict. 1: 320. 1831. Species No. 28.
*V. delphinifolia* Nutt. in Torr. & Gray, Fl. No. Am. 1: 136. 1838.

About two years before his death, January 30, 1888, Gray in the Bot. Gaz. 11: 254, Nov., 1886, said of *V. pedatifida* Don.: "Its affinities are with *V. palmata,* indeed [it] is probably only a marked geographical variety of that species." But in the Synop. Fl., p. 196, Oct., 1895, it is admitted without comment between *V. pedata* and *V. palmata.* In the paper above cited Gray speaks of specimens collected at Concord, Mass., by Tuckerman "which would surely pass for *V. pedatifida* if from the valley of the Mississippi." They were doubtless *V. Brittoniana* and its associated *V. pectinata.*

*V. pedatifida* is a species of the Atlantic Basin, also abundant in the prairies of the Middle West, ranging from near Sandusky, Ohio, northwest to Saskatchewan and southwest to Oklahoma and New Mexico.

The name is singularly inappropriate, for the middle segment of the leaf is always dissected, while in the strictly pedate leaf it is never dissected. The blade of *V. pedatifida* is primarily 3-parted, and when well developed each of the three segments is further trisected, and then each of these subdivisions once more cut into 2-4 lobes.[1]

Our line-drawing is of a herbarium specimen from prairie near Muskogee, Okla., Brainerd, coll., April 11, 1910. The species is No. 120 of my Distribution of Eastern North American Violets, 1910.

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[1] See pl. 1, fig. 2, Bull. Torr. Cl. 38. Jan., 1911—a leaf-blade having in all some 30 incisions.

**Viola septemloba** LeConte, Annals N. Y. Lyceum 2: 141. 1826. Species No. 29.

This species is here well described and is said to grow in Carolina and Georgia only in pineries, through what is called the lowlands. "Its peduncles often eight inches high are adorned with flowers two inches in diameter." This statement is exactly borne out by his beautiful water-color, which the present writer had the privilege of examining when it was owned by Greene.

The treatment of *Viola* in Eaton's Botany, widely used till 1850, is hardly more than a translation of LeConte's monograph of 1826. But Torrey and Gray as early as 1838 in their Flora of North America, say "we fear that this species (*V. septemloba*) is only a variety of *palmata*." In Gray's paper on *Viola* in 1886 it is called a "variety of *palmata*," and in the Synop. Fl., Oct., 1895, it is simply cited as synonym of *V. palmata*. In the first edition of Small's Southern Flora in 1903, the plant at length regained recognition in American botany after suffering a well-nigh total eclipse for over half a century.

The present known range of the species is from southeastern Virginia to Florida, in the tide-water plain and west to Biloxi, Miss. The foliage of the plant is extremely variable. "The first leaves often, and sometimes all the leaves, uncut; the others primarily 3-lobed, 3-cleft or 3-parted with widely open sinus, the middle segment uncut, relatively long and broad, usually narrowed at the base, the lateral segments (sometimes uncut) but generally pedately cleft into 2-4 narrow divergent parts that become smaller toward the base of the leaf."[1]

*V. septemloba* has been often confused with *V. Brittoniana,* a cut-leaved species of the same group and of similar habitat. But they differ in three respects: (1) The seeds of *V. Brittoniana* are buff and 1.6 mm. long; those of *V. septemloba* are dark brown and 2 mm. long. On weighing 200 seeds of each, those of *V. septemloba* were found to be over 93 percent the heavier, or nearly twice as large. (2) The leaves of *V. Brittoniana* are palmately parted, all of the three primary segments being again twice or thrice split; those of *V. septemloba* are pedately parted. (3) *V. septemloba* is found only in southeastern Virginia and southward, *V. Brittoniana* only in Virginia and northward.

The color-plate of *V. septemloba* represents a pressed plant from a pine woods near Summerville, S. C., Brainerd coll., March 25, 1907, and is the copy of a water-color by Mathews. Specimens are to be seen in my Distribution, 1910, Nos. 150-153.

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[1] Brainerd in Small's Southern Fl., 2nd ed. 1913.

See color-plate, Species No. 29, opposite page 68.

**Viola Selkirkii** Pursh, Goldie, Edinb. Phil. Jour. 6: 324. 1822. Species No. 30.

This, one of the most distinct of North American violets, was first discovered on hills about Montreal, Que., and described[1] by John Goldie, a Scotchman who collected plants in North America from 1817 to 1820. The violet seems to have been seen and named by Pursh, for in 1822 it was published in the Edinburgh Phil. Jour. (6: 324) as "*V. Selkirkii* Pursh, by Goldie." The Scotch collector in 1844 emigrated to Ayr, Ont., where he died June, 1886, at the age of 93. In a letter to Hooker,[2] Gray wrote, "Old Goldie, your father's correspondent lange syne, died only this summer, very old."

Stations for *V. Selkirkii* rapidly multiplied after Goldie's discovery. True to its name—after the sailor Alexander Selkirk, the Robinson Crusoe of Defoe—this violet dwells in the solitude of cold mountain forests, and is reported from as far north as Greenland. Gray discovered that the species was circumpolar, occurring in Russia, Japan and Kamtschatcha. Happily, the Eurasian plants were described later than 1822, and *V. Kamtschatica* Gingins and *V. umbrosa* Fries are only synonyms of *V. Selkirkii* Pursh.[3]

Some recent finds are interesting. The writer has a specimen collected by Prof. J. K. Henry, June 13, 1895, from low woods on terraces of the Skeena River, B. C., in lat. 55° 15′ N., long. 127° 41′ W. and from slopes of Mount Bonaparte, Okanógan County, Wash., Eggleston, 13055 and 13057. July, 1916. This is strongly confirmatory of Gray's opinion that many of our northwestern American plants have reached us from northern Asia across the Bering Sea, often migrating southward along the Rocky Mountains, even to Colorado, from which State I have received many specimens of *V. Selkirkii* and of *V. biflora* L. another Eurasian species.

Wilhelm Becker, a violet specialist places *V. palustris* and *V. Selkirkii* on the basis of their disk-form stigmas in a distinct group. The former is stoloniferous, the latter not. Furthermore, *V. Selkirkii,* very soon after petaliferous flowering, bears cleistogamous flowers in abundance.

The plant shown in our color-plate came from the mountains to the east of Middlebury, Vt., collected April 25, 1913. See also Nos. 148 and 149 of my Distribution, 1910.

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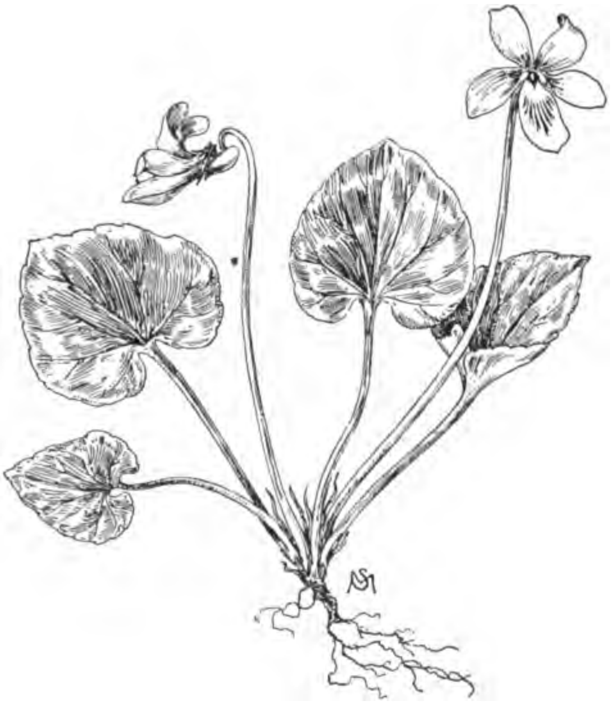
[1] Dr. Gray, Bot. Gaz. 11: 254, 272. Nov., 1886.
[2] Sept., 1886, Letters of Asa Gray, p. 785.
[3] See Gray Man., ed. 5, p. 78, 1874.
**See color-plate, Species No. 30, opposite page 68.**



Species No. 31—**Viola palustris** L.

**Viola palustris** L. Sp. Pl. 934. 1753. Species No. 31.

The line-drawing is a copy of Reichenbach's Ic. Fl. Germ. iii. t. 2.

In Wilhelm Becker's Violae Europaeae *V. palustris* is associated with *V. Selkirkii,* both having a disk-form stigma produced into a short beak, but differing in that *V. palustris* has creeping stolons and *V. Selkirkii* does not.

As the specific name indicates the plant is a denizen of swamps or of cold, wet mountains. The species is widespread in the highlands of Europe and northern Asia, and is found in North America from Labrador to Alaska, extending southward in the east to the high mountains of New England, and in the west southward along the Rocky Mountains to Colorado, and along the Pacific Coast to Washington.

The foliage is glabrous; the petals pale violet or sometimes white.

**Viola renifolia** Gray, Proc. Am. Acad. 8: 288. 1870. Species No. 32.

Gray's paper reads as follows: *Viola renifolia,* n. sp. Rhizomate floribusque *V. blandae* vel paullo majore; foliis reniformibus (adultis saepius poll. 2 latis) utrinque cum petiolo villoso-pubescentibus; scapo pubescente.[1]

"This violet was first brought to my notice by Miss Shattuck of Mount Holyoke Seminary, who collected it at, or received it from, East Elba, New York. Later, Mr. Henry Gilman sent it from Ontonagon,[2] Lake Superior, and now I have fresh specimens and the living plant from Mr. Frank A. Sherman of Hanover, N. H. Also specimens from the colder parts of Oneida County, N. Y., from Professor Paine. It grows in company with *V. blanda,* which it closely resembles as to the flower, but the leaves are more like those of *V. palustris;* yet they are more strictly reniform and are conspicuously beset with pale, soft and tender, lax hairs."

To this Eggleston adds: I remember now Professor Jessup telling me that the type location for *V. renifolia* was the "Bottomless Pit in Hanover" (N. H.). Prof. Frank A. Sherman, my professor of mathematics, also told me * * that the "Bottomless Pit in Hanover is a great sphagnum bog that was a favorite botanizing place of ours."

In his final revision of *Viola*[3] Gray unites under *V. blanda* "two forms which in their extreme would seem specifically distinct, viz.: var. *palustriformis,* and 'var. *renifolia,*' which seems quite different from the ordinary state of *V. blanda* . . . . (but) is so connected with the preceding variety that it can not be kept distinct." Just how it is connected is not explained, but it was probably due to the unrecognized presence of two other good species, *V. incognita* and *V. pallens,* the latter surmised to be such by DeCandolle as early as 1824.[4] See Rhod. 7: 245-8. Dec., 1905.

A similar confusion and perplexity is to be seen in Greene's publication of *V. Brainerdii,*[5] "by no means," he says, "an easily differentiated segregate of *V. renifolia.*" Some of his material, No. 17 of Pollard's distribution and Watson's plant from Prince Edward Island, was *V. incognita*—the "unrecognized" masquerader that for many years was a hidden source of perplexity to the student of *Viola.*

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[1] Rootstock and flowers of *V. blanda* or somewhat larger; leaves reniform (when full grown quite often 2 in. broad) on both surfaces and the petiole villous-pubescent; scape pubescent.

[2] In lat. 46° 49′, long. 89° 27′ W.

[3] Bot. Gaz. 11: 255. 1886.

[4] See under *V. pallens.* Prodromus 1: 295. 1824.

[5] Pitt. 5: 89-90. Nov., 1902.

The publication of *V. renifolia* Gray, var. *Brainerdii* (Greene) Fernald[1] speaks for itself; however, attention should be called to a name 13 years older, *V. mistassinica* Greene, Pitt. 4: 5. Jan., 1899. The types in the Herbarium of the Canadian Geological Survey are: No. 1, from damp, mossy woods about Lake Mistassinai, Quebec,[2] that empties into Hudson Bay; No. 2, from Hamilton River, Labrador; and No. 3, from the east shore of Hudson Bay, the last two stations being in about 55° north lat. With these should be cited a station near Hazelton on the Skeena River in northern British Columbia.[3] J. K. Henry coll., June 15, 1895, and a station at Golden, B. C., where the Canadian Pacific R. R. leaves the Columbia River to cross the Rocky Mountains, and from slopes of Mount Bonaparte, Okanógan County, Wash., Eggleston, 13056, July, 1916. These far northern plants have surely diverged in habitat and aspect a long way from the typical *V. renifolia* of Hanover, N. H. See Nos. 129, 130 and 131, Distribution of 1910.

*V. renifolia* differs from the two other woodland plants—*V. incognita* and *V. blanda,* its nearest allies—in three respects: (1) In its reniform leaves, (2) in the absence of stolons, (3) in having beardless petals. In these characters it approaches the purple-flowered species *V. Selkirkii* Pursh.

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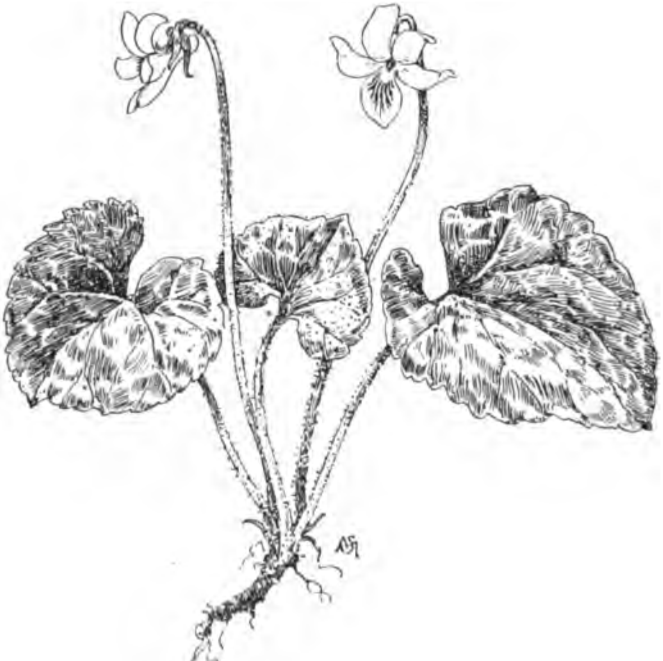
[1] Bull. Torr. Cl. 38: 8. Jan., 1911; and Rhod. 14: 86-8. May, 1912.
[2] Lat. 51° N.
[3] Lat. 55° N., Long. 128° W. Both specimens in Herb. E. B.
See color-plate, Species No. 32, opposite page 69.



Species No. 33—**Viola incognita Brainerd**

**Viola incognita** Brainerd, Rhod. 7: 248. Dec., 1905. Species No. 33.

The circumstances leading to the publication of this white violet are stated in the Rhodora article above cited. But the specific name has not always been understood. The word means not only unknown, but unrecognized. This abundant species, ranging from Newfoundland to the Dakotas and south to eastern Tennessee, had for many years been a source of confusion and perplexity, often playing the part of a masquerader and passing as one of the older species. A striking instance of this is to be seen in Greene's publication of *V. Brainerdii,*[1] "by no means," he says, "an easily differentiated segregate of *V. renifolia.*" This was plainly due to the fact that some of his material, No. 17 of Pollard's Distribution and L. W. Watson's plant from Prince Edward Island, was *V. incognita.* Many specimens in my own and in other herbaria determined before 1905 as *V. amoena* LeConte, *V. blanda* Willd., or its var. *palustriformis* Gray, prove to be *V. incognita,* or var. *Forbesii* Brainerd, Bull. Torr. Cl. 38: 8-9, fig. 1, Jan., 1911, named for Mr. F. F. Forbes of Brookline, Mass., an accurate and critical student of *Viola.*

This approaches *V. blanda* Willd. as respects pubescence, probably as a result of vicinism in the more or less remote past; but in other respects it is like typical *V. incognita.* Its characters appear now for the most part stable and its stations are often quite remote from those of *V. blanda.* It is, however, not unlikely that some instances occur of recent hybridism. A suspected hybrid may be tested by raising from its cleistogamous seeds a brood of offspring, which, if reverting variously to the characters of the suspected grandparents, prove the hybrid nature of the parent. See Bull. Torr. Cl. 40: 249-260, plates 15, 16, 17, June, 1913, for examples of these experimental cultures.

This species is represented by Nos. 67, 68 and 69 of my Distribution, 1910.

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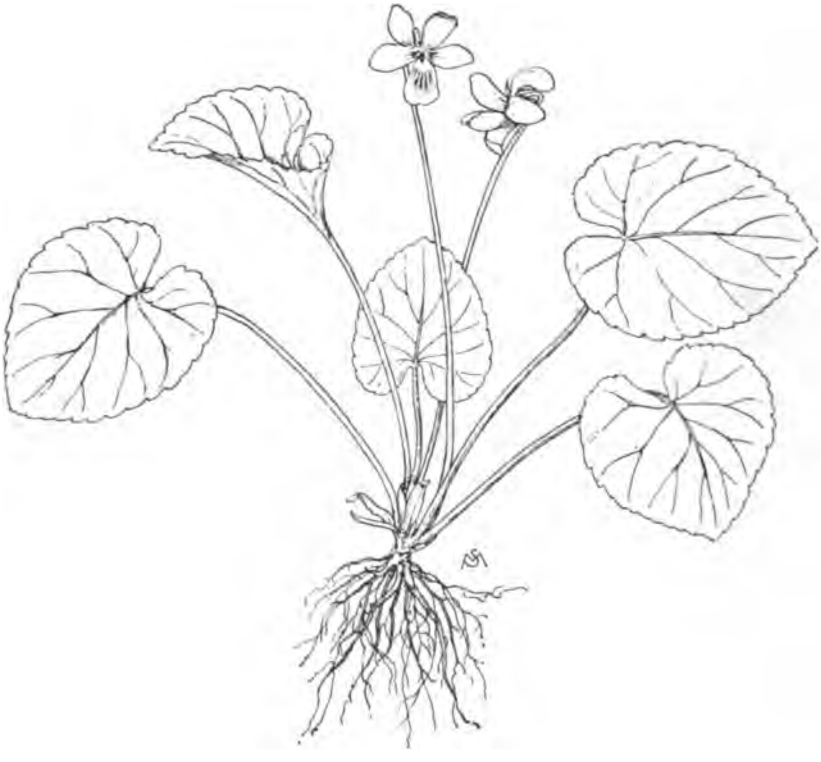
[1] Pitt. 5: 89-90. Nov., 1902.



Species No. 34—**Viola blanda** Willd.

**Viola blanda** Willd., Hort. Berol., t. 24. 1806. Sp. No. 34.

Willdenow in his description emphasizes the fact that the lateral petals are beardless, stating it in three places; but he overlooks another important character, the minute white hairs on the upper surface of the leaves, calling them glabrous—"foliis glabris." His hand-colored plate, two copies of which I have examined and from which our line-drawing is made, is excellent. In this plate the peduncle, petiole and even the midrib have a pink color, often found in this species when growing in boggy soil, but rarely seen in *V. pallens*.

The medley of names wrongly used for *V. blanda* is best shown by a tabular list of the synonyms:

**Viola blanda,** Willd., Berol. t. 24. 1806.
*V. amoena* LeConte,[1] Ann. Lyc. N. Y. 2: 144. 1826; not Symons. 1798.
*V. Leconteana* Don, Gen. System. 1: 324. 1831.
*V. alsophila* Greene, Pitt. 4: 7. Jan., 1899.

The species is far less hardy than *V. pallens* and ascends to high altitudes only in the South. On shaded rocks in Tryon, N. C., forms occur in which the upper surface of the leaf is quite glabrous. The range of *V. blanda* is from western Quebec and western New England to Minnesota, and south in the Appalachian Mountains to Georgia. It is represented in Nos. 15 and 16 of my Distribution of Eastern North American Violets, 1910.

The line-drawing is a copy of Willdenow's t. 24, 1806.

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[1] LeConte's "*V. blanda*" was the plant now considered *V. pallens*, as is shown both by his description and by his water-color labelled by him "blanda." Of this a tracing is before me; it is indubitably *V. pallens*.

**Viola pallens** (Banks) Brainerd, Rhod. 7: 247. Dec., 1905. Species No. 35.

This was originally described by DeCandolle[1] from herbarium specimens collected by Banks in Labrador several years earlier, bearing the manuscript name *"Viola rotundifolia* Mich. var. *pallens."* De Candolle's brief description is "glabra, sepalis acuminatis—in Labrador et Kamtschatka. In eadem ac alpha? An species?" which seems to mean that he doubts if it is Michaux's species and suspects that it is something else.

Only two years later (in 1826) LeConte in his monograph of *Viola* conceived the plant to be the *V. blanda* of Willdenow and used the name *V. amoena* for the true *V. blanda*—an invalid name for which Don substituted *V. LeConteana.* In this error LeConte was followed by subsequent botanists until 1905, when Britton, studying the plate of Willdenow, found that it clearly represented what was currently passing as *V. LeConteana.* Thus the long-standing error of LeConte was corrected, and the plant of Willdenow received just recognition.

The question now arose what should we call the false *V. blanda* of LeConte. Here the thorough work of Fernald at the British Museum in 1903 solved the problem. He found there the type of Bank's *rotundifolia* Mich. var. *pallens,* photographed his sheet of seven plants. and was convinced that three of them were plainly our common northern plant and that *"pallens"* was the correct specific name for LeConte's *V. blanda.* Thus after a period of 79 years the names of these two white violets were finally established.

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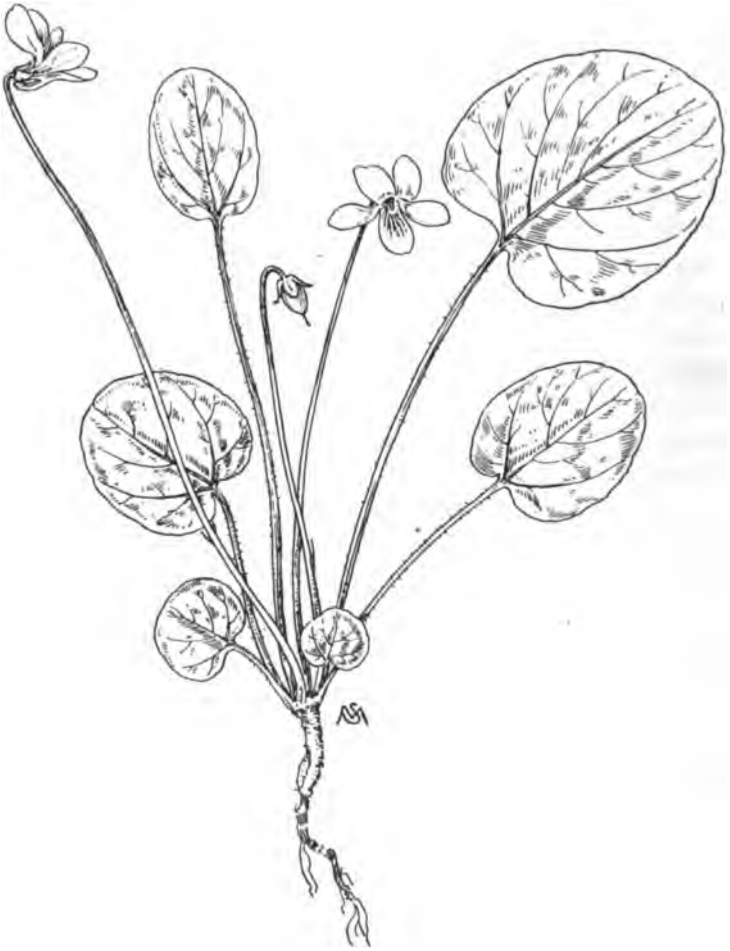
[1] Prodromus 1: 295. 1824.

**See color-plate, Species No. 35, opposite page 69.**

*V. pallens* is a plant of much colder habitat that *V. blanda.* It occurs in Labrador, Newfoundland, Gaspe County, Que,, and near the summit of mountains like Mansfield (Vt.) and Greylock (Mass.). It ascends some 2,000 feet higher than *V. blanda,* is a denizen of open bogs rather than of rich woodlands, and is at home in springy land and along cold brooks. Its nearest ally is *V. Macloskeyi* Lloyd, a species which is readily distinguished from *V. pallens* by the entire, or at most obscurely crenate, margin of the leaf.

Plants hardly separable from *V. pallens* have been collected by Prof. J. K. Henry at Stanley Park, Vancouver, B. C., and at other stations northward along the coast to the terraces of the Skeena River in lat. 55¼° N.

Our color-plate is based on a herbarium specimen collected in Middlebury, Vt., June 3, 1915, along the outlet of a cold spring at the base of the Green Mountains in eastern Middlebury. It is represented by Nos. 94 and 95 of my Distribution, 1910.



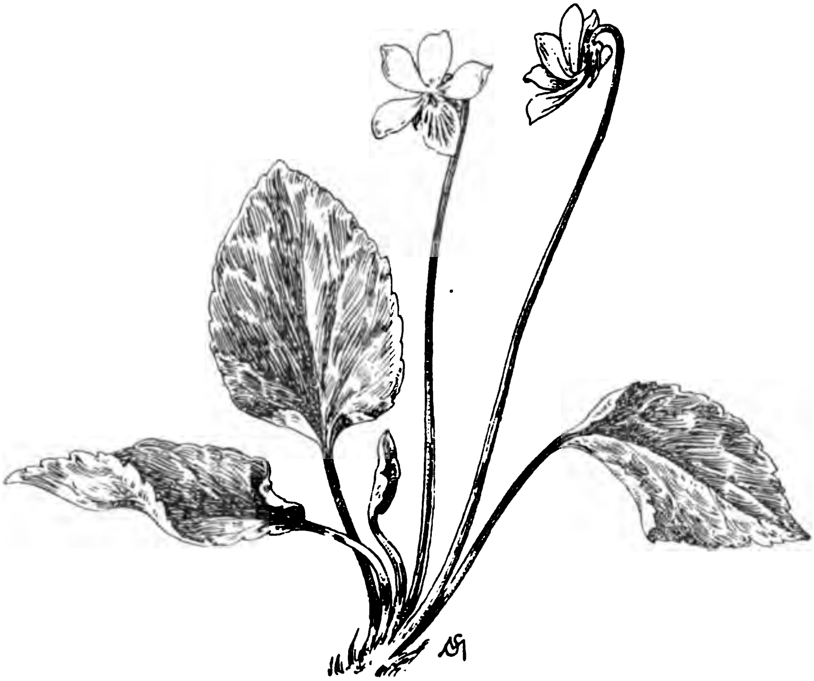
Species No. 36—**Viola Macloskeyi** Lloyd

**Viola Macloskeyi** Lloyd, Erythea 3: 74. May, 1895. Species No. 36.

The type in the Bronx Park Herbarium was collected July 22, 1894, at the base of Mount Hood, Ore., lat. 45° 20′, about 50 miles east of Portland. It was named in honor of Prof. Geo. Macloskey of Princeton University. It had been collected five years earlier by Mrs. Peckinpah in the mountains of Fresno County, Cal., and was published 12 years later as *V. anodonta* by Greene in Pitt. 5: 32. Sept., 1902. I collected a specimen July 7, 1897, at Meisner's Ranch, Eldorado County, on my first visit to California, and on my second visit in 1915 found it at many stations in the Truckee River Valley, Placer County, and have received several specimens from Mrs. Viola Brainerd Baird, Eggleston and others.

In 1910, F. F. Forbes sent me ample herbarium material grown in Brookline, Mass., of a plant originally from Banff, Alberta. I was surprised to find the specimens labelled "*Viola pallens* (Banks) Brainerd," as they were unmistakably *V. Macloskeyi.* It revealed, however, the close relationship of the two species and gave a new station for *V. Macloskeyi,* 377 miles further north than Mount Hood, about the distance in an air line from Philadelphia to Ottawa.

The line-drawing is based on a herbarium specimen from Deer Park, Placer Co., Cal., alt. 6,200 ft., Mrs. Baird, coll., July, 1910.



Species No. 37—**Viola primulifolia** L.

**Viola primulifolia** L. Sp. Pl. 934. 1753. Species No. 37.

This is the largest species of the white violets that grow in wet, open places, and has the widest range, extending along the coast from New Brunswick to Florida and Texas. In the North the foliage is usually glabrous, but in the South it is often notably pubescent, with petioles often broadly winged. This form was called var. *villosa* in the Manual of Eaton and, later, var. *australis* by Pollard.[1] In late summer and in autumn the species is propagated by leafy and creeping floriferous stolons.

Specimens of var. *villosa* Eaton are to be found in Nos. 123, 124, 125 of my Distribution of Violets, 1910.

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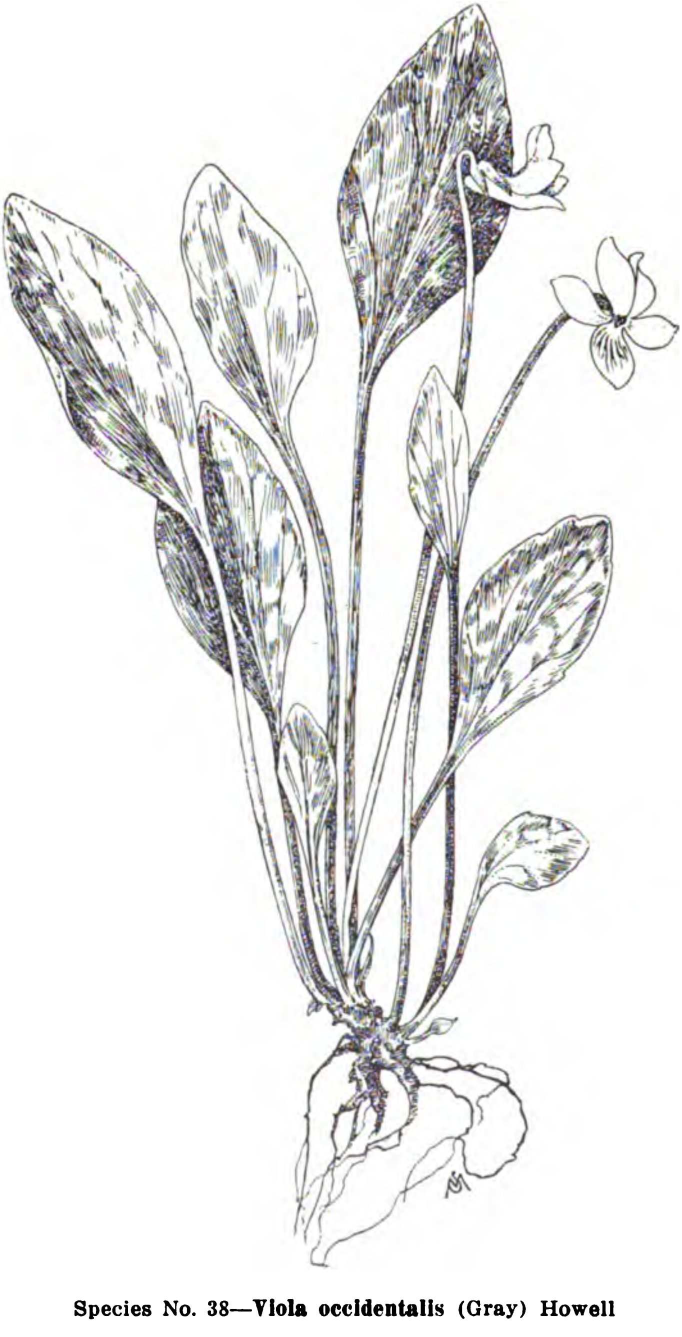
[1] Bot. Gaz. 26: 342. Nov., 1898.



Species No. 38—**Viola occidentalis** (Gray) Howell

**Viola occidentalis** (Gray) Howell, Fl. N. W. Am. 69. Mar. 10, 1897. Species No. 38.

Though found only on the Pacific Coast this violet seemed so nearly related to *V. primulifolia,* over 1,800 miles to the southeast, that Gray[1] regarded it as only a variety of the eastern plant. But a careful study of the type in the Gray Herbarium, collected at Waldo, Ore., June 5, 1884, and of other data convinced me that Howell was justified in publishing it as a valid species in 1897. His description is detailed and as exact as could be expected when based on only a single collection. This conviction is strongly confirmed by the study of a specimen in my possession from Gasquets, Del Norte Co., Cal., not far from the type station, Miss Alice Eastwood, collector, April, 1907; also by two specimens in the National Herbarium. (1) F. A. Walpole, 2114, 10 miles west of Waldo, Ore., April 26, 1902; (2) C. V. Piper, 6107, 8 miles south of Waldo, Ore., June 14, 1904.

An admirable water-color of the type in the Gray Herbarium was painted for me in June, 1918, 34 years after its collection by Howell; from this was made the line-drawing here presented.

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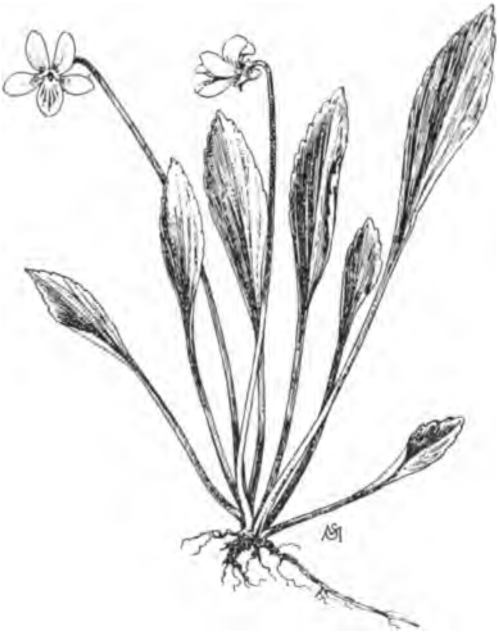
[1] *V. primulifolia* L. var. *occidentalis* Gray. Bot. Gaz. 11: 225. Nov., 1886; and Synop. Fl., p. 198.

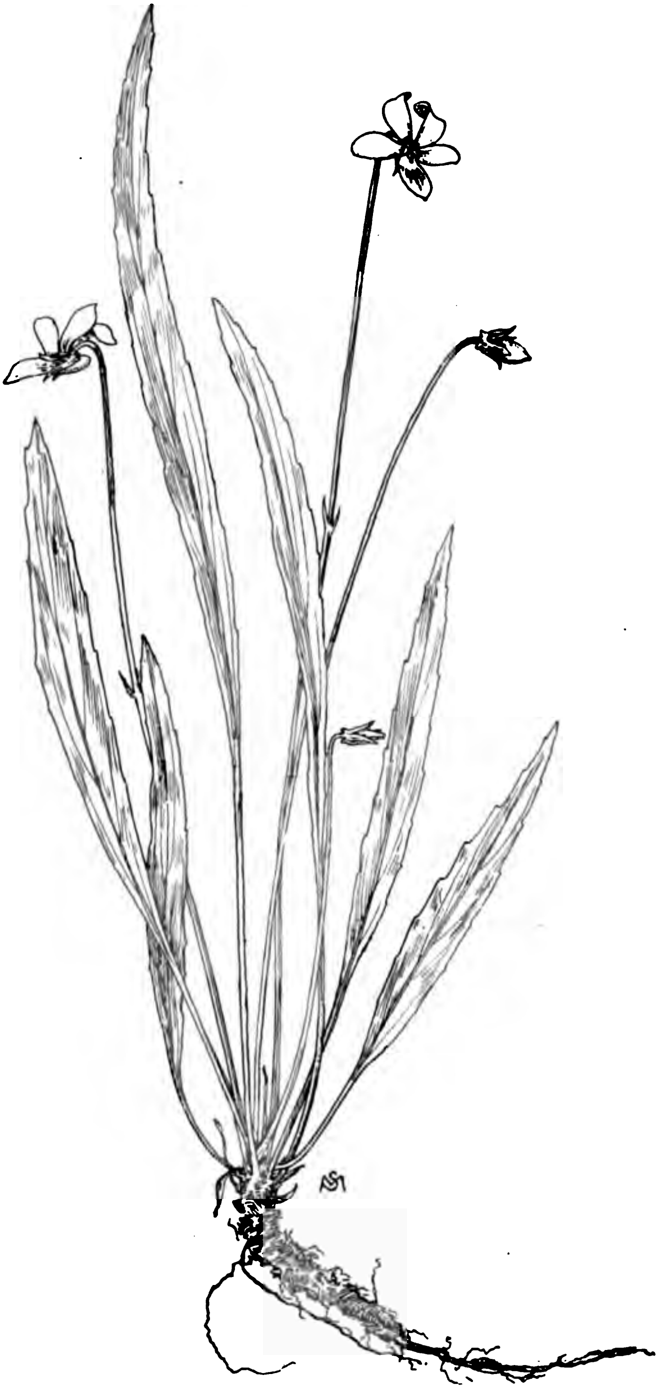


Species No. 39—**Viola lanceolata** L.

**Viola lanceolata** L. Sp. Pl. 934. 1753. Species No. 39.

The habitat of this eastern white violet is the same as that of *V. primulifolia,* but its range is more to the northwest—from Nova Scotia to Minnesota, but southward only to the Piedmont plateau, the northern border of the Coastal Plain. This northwestern range is shown by the fact that no station for *V. primulifolia* is known in Vermont, but for *V. lanceolata* there are five.

*V. lanceolata* at vernal flowering is a small plant, but its foliage in summer often attains the height of 10 or 12 inches. Later it puts forth in favorable soil numerous stolons that root freely, branch and in the following spring bear at their tips new flowering plants. Specimens illustrating this method of propagation are to be seen in Nos. 70 and 71 of my Distribution of Eastern North American Violets, 1910.



Species No. 40—**Viola vittata Greene**

**Viola vittata** Greene, Pitt. 3: 258. Feb., 1898. Species No. 40.

This species of open bogs and borders of marshy ponds is confined to the southern coast from Georgia to Texas. Before its recognition by Greene it masqueraded as *V. lanceolata* L. LeConte's water-color of *V. lanceolata* represents, not the species of Linnaeus, but *V. vittata.* The specific name alludes to the resemblance of the foliage to the fronds of Vittaria, a genus of the Fern family. The mature leaf of *V. vittata* is linear, 4-10 mm. wide, 15-30 cm. long, mucronately serrulate. Unmindful of Greene's publication Pollard in 1901[1] published it as *V. denticulosa.*

Our line-drawing is of a herbarium specimen collected in Florida, March 30, 1909, along the road from DeLand to the DeLeon Springs. Characteristic specimens may be seen in Nos. 178 and 179 of my Distribution of Violets, 1910.

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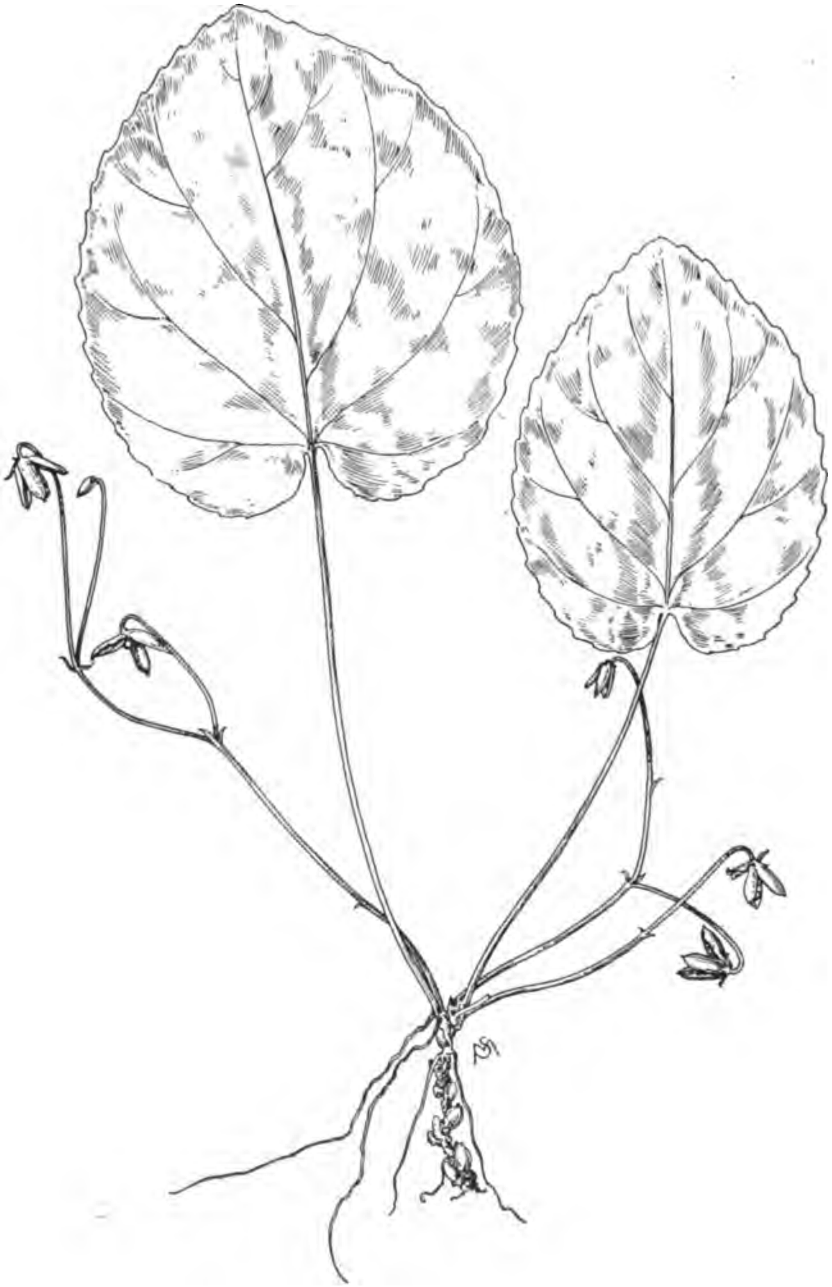
[1] Bull. Torr. Cl. 28: 475.



**Species No. 41—Viola rotundifolia** Michx.

**Viola rotundifolia** Michx., Fl. Bor. Am. 2: 150. 1803. Species No. 41.

This violet is readily distinguished when seen in vernal flowering, but has been a source of perplexity, as it appears in autumn. To this autumn form Pursh gave the name *V. clandestina,* cautiously adding: "*V. rotundifolia* Michx., Fl. Amer. 2, p. 150, in shady beech woods among rotten wood and rich vegetable mould . . . . flowers of a chocolate brown." Concerning this correct surmise, Schweintz dogmatically states[1] that Pursh's plant and Michaux's "can have no affinity whatever"; yet they have proved to be identical! We now understand the plant's peculiar method of bearing in late summer cleistogamous flowers and fruit on raceme-like stems—not on stolons, as these stems never root nor produce new plants, as seen in line-drawing.[2] The white violet *V. renifolia* is like *V. rotundifolia* in having no stolons, in this respect differing from all other white violets, for these bear cleistogamous flowers and fruit in abundance on stolons.

This unique species is usually found in cold, rich woodlands from Maine west to Lake Huron and south along the Alleghanies to Rabun County, Ga. Its affinity to *V. orbiculata* of northwestern America is manifest, though the two species grow in regions widely apart. This relationship is seen in the shape of the leaves as is indicated by the specific names, by the yellow vernal flowers, and by the later cleistogamous flowers on raceme-like stems. The two points of difference are: (1) The presence of several small leaves on the raceme-like stems of *V. orbiculata;* but only an occasional one on those of *V. rotundifolia;* (2) the seeds of *V. orbiculata* are brown and relatively broad; those of *V. rotundifolia* grayish white and smaller.

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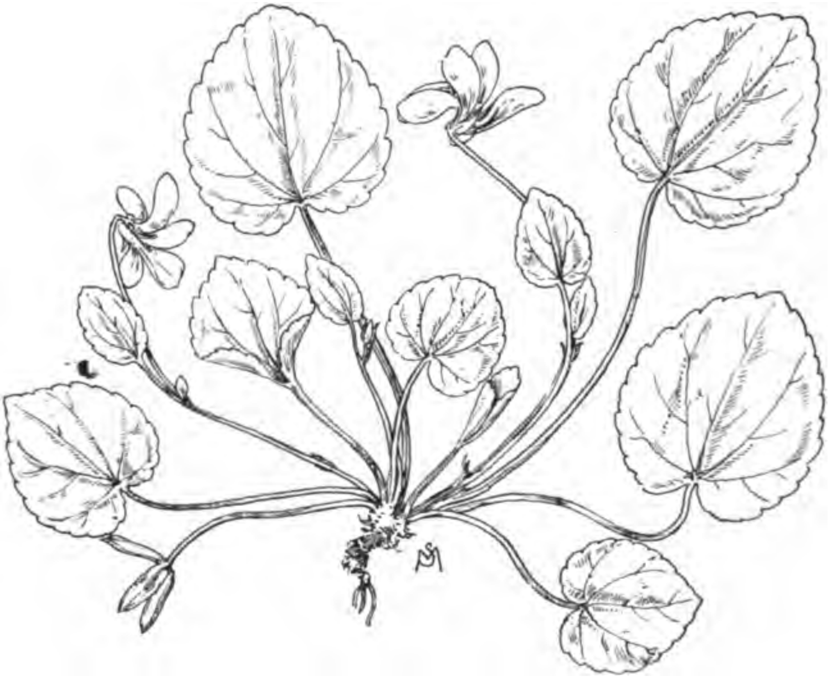
[1] Am. Jour. Sci. 5: 63. 1822.

[2] Cf. Greene in Pitt. 3: 255. Dec., 1897.

See also color-plate, Species No. 41, opposite page 100.



Species No. 42b—**Viola orbiculata** Geyer

**Viola orbiculata** Geyer, Hook. London Jour. Bot. 6: 73. 1847. Holz. Cont. U. S. Nat'l Herb. 3: 214-5, pl. 4. 1895. Species No. 42.

This rare and beautiful violet of northwestern America commemorates a talented and enthusiastic young German, Carl A. Geyer, who first collected and named it. In Hooker's Jour. Bot. 7: 181-3, 1855, appeared an interesting obituary of Geyer by Dr. H. G. Reichenbach of Berlin, from which we learn that in February, 1834, Geyer, when hardly more than 23 years of age, left Dresden for North America, to satisfy his thirst for exploration. For nearly ten years he endured hardship due to illness and to abuse from Indians. On November 13, 1844, he sailed from Vancouver Island and reached England by way of the Hawaiian group in May, 1845. The following September, much broken in health, he returned to Dresden, where he died November 21, 1853.

The type of *V. orbiculata* was collected in dark, shady woods of *Thuja gigantea* in the Coeur d'Alene Mountains of Idaho, June, 1844, and was published by Hooker in the London journal above cited, as a doubtful *V. rotundifolia* with the statement that if it "proves distinct Mr. Geyer's manuscript names of *V. orbiculata* should be adopted." The plant was first collected, though not published, by David Douglas. Gray, however, to the last held it to be a variety of *V. sarmentosa;* but it was recognized at the National Herbarium as a valid species and illustrated by a plate representing both its early and its late summer stages.

As known at present, the stations for *V. orbiculata* are in western Montana, northern Idàho, Oregon, Washington and North in British Columbia to lat. 55¼°, long. 127° 40′. Our color-plate and line-drawing are based on a plant from the last named station, Prof. J. K. Henry, coll., June 17, 1915, in wet, mountain woods (altitude 4,200 feet) near Hazelton, B. C. The species is plainly a near relative of *V. rotundifolia,* though the tracts where the two species occur are more than 1,600 miles apart, about the distance from New York City to Denver, Colo.

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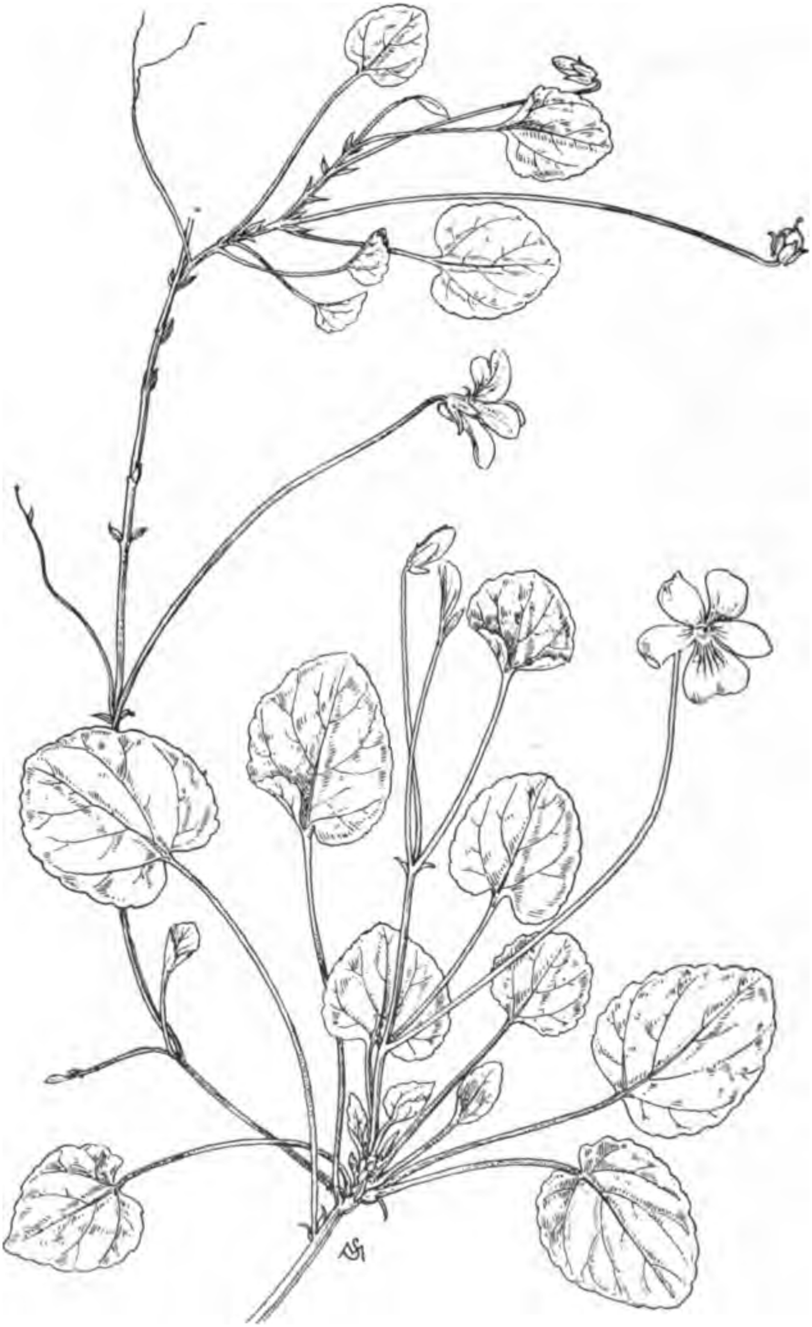
See also color-plate, Species No. 42, opposite page 100.



**Species No. 43—Viola sarmentosa Dougl.**

**Viola sarmentosa** Dougl. in Hooker's Fl. Bor. Am. 1: 80. 1830.[1]
Species No. 43.

The most northern station known for *V. sarmentosa* is Victoria, B. C. "Dry woods and banks Shawingan, Vancouver Island, J. K. Henry, No. 9112, May 9, 1915." Thence it ranges southward to Marin County, Cal., on the coast, but not along the Sierra Nevada as does *V. praemorsa.* In Torrey and Gray's Flora of 1838, a station for *V. sarmentosa* is cited "near Walla Walla, Mr. Townsend," 190 miles east of Portland, Ore. This was doubtless *V. orbiculata,* as was also the plant reported from Idaho as *V. sarmentosa* in the Synop. Fl., p. 199.

My herbarium contains the following additional specimens:

1. Salem, Ore., Geo. M. Darrow, a live plant unnamed, sent September 11, 1911.
2. Fort Bragg, Mendocino Co., Cal., Miss Alice Eastwood, August, 1912.
3. Fort Bragg, Mendocino Co., Cal., Mrs. Viola Brainerd Baird and E. Brainerd, August 20, 1915.
4. Marin County Cal., M. E. Parsons, May 5, 1912.
5. Marin County, Cal., Miss Eastwood, June 6, 1899, No. 16, North American Violaceae, United States National Herbarium.
6. Marin County, Cal., Mrs. Viola Brainerd Baird and E. Brainerd, under redwoods, Mount Tamalpais, August 7, 1915.

In Pitt. 4: 8, Jan., 1899, Greene renamed this species *V. sempervirens,* because *"V. sarmentosa"* had been given by an old world botanist in 1808 to a plant that later proved to be *V. odorata* L. But by the international code the name *V. sarmentosa* Dougl. is not thereby invalidated. It is, however, interesting to note that the leaves of the species are evergreen, i. e., sempervirent, and coriaceous.

The line-drawing is made from a herbarium specimen, Mount Vision, Inverness, Marin Co., Cal., Mrs. Viola Brainerd Baird coll., March 26, 1916.

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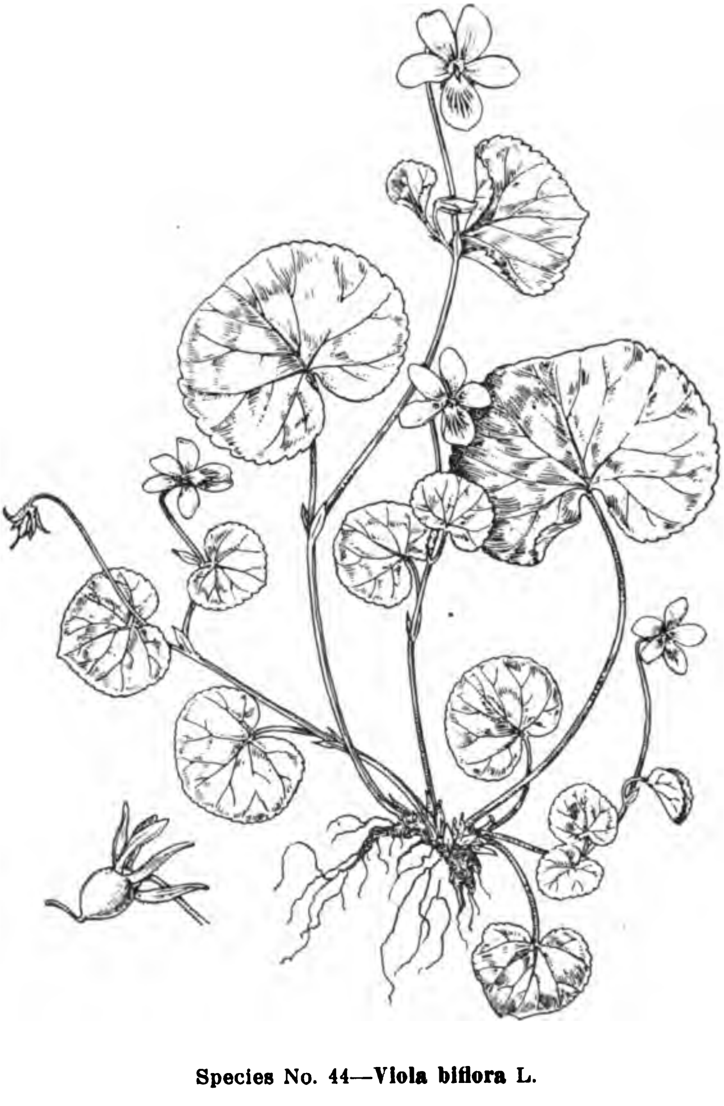
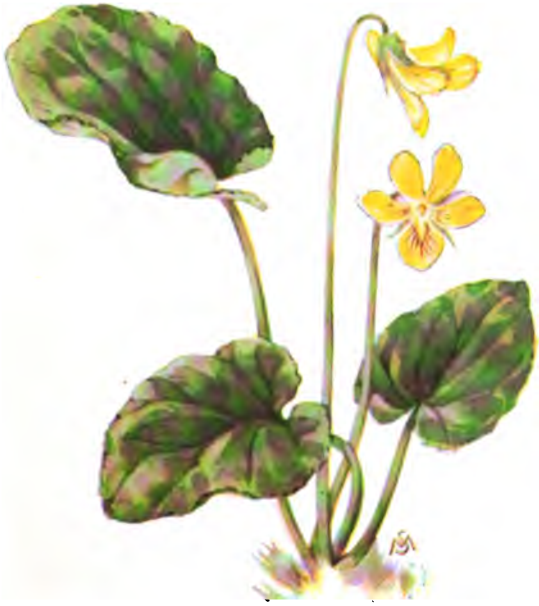
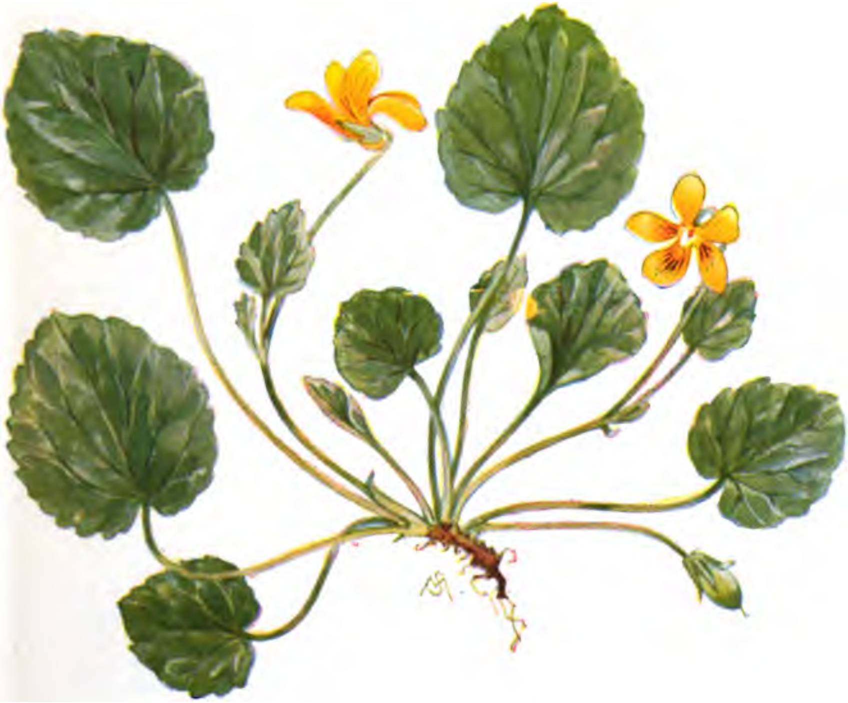
[1] It should be borne in mind that at the date of this publication and until 1845, British North America extended on the Pacific Coast well south of the Columbia River.

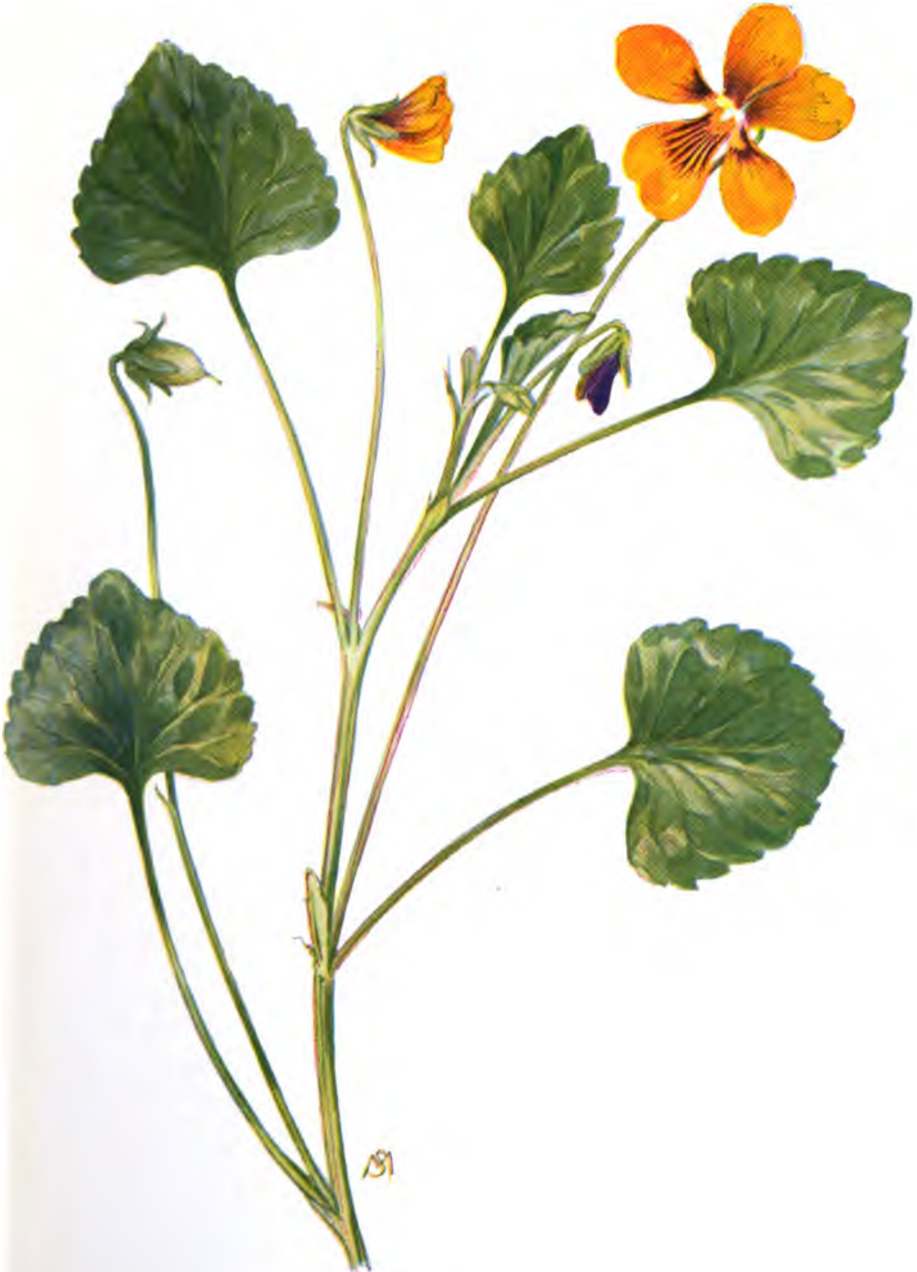


Species No. 44—**Viola biflora** L.

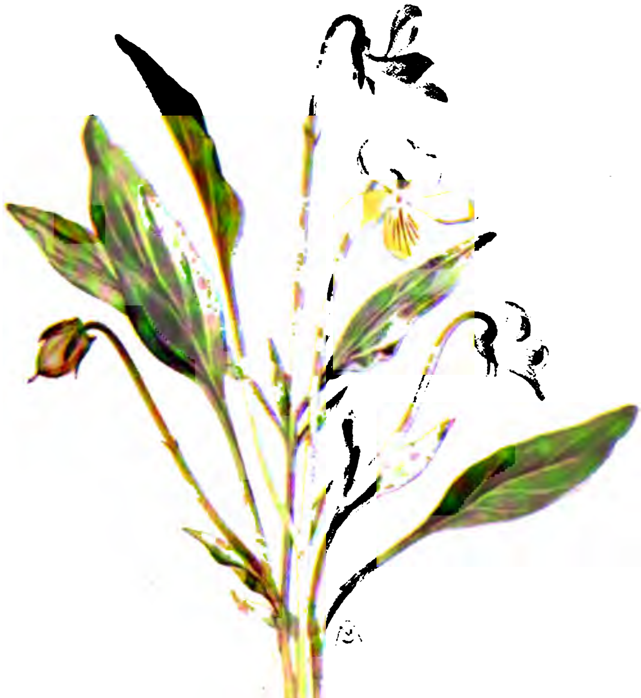

Species No. 41a—**Viola rotundifolia** Michx.



Species No. 42a—**Viola orbiculata** Geyer



Species No. 45—**Viola pedunculata** Torr. & Gray



Species No. 46a—Viola Nuttallii Pursh

**Viola biflora** L. Sp. Pl. 936. 1753. Species No. 44.

This species is a notable instance of the migration of a widely distributed species of the Old World to North America across the Bering Sea and southward along the Rocky Mountains to Colorado. The genus *Viola* was not alone in this migration. Gray, after a study of the Flora of Japan, was convinced that an "interchange of temperate species between North America and Europe had taken place by way of Asia."

In his monograph, Violae Europaeae, Wilhelm Becker has given in detail the distribution of *V. biflora.* It is found in nearly all the high mountains from the Pyrenees through Switzerland, Germany, Austria, Scandinavia and Russia, and in Siberia, West and North China and Japan.

The characters of the species are so unique that European specialists assign to *V. biflora* alone one of the three special sections into which they divide the genus. Our line-drawing—an exact copy of the plate of Reichenbach made in 1839[1]—shows the general character of foliage, flowers and fruit, but falls far short of the beautiful coloring to be seen in a painting by Mathews.

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[1] Reichenb. Ic. Fl. Germ. iii, t. 1, fig. 4489.

**Viola pedunculata** Torr. & Gray, Fl. No. Am. 1: 141. July, 1838. Species No. 45.

We copy in full the original description of this species, probably from the pen of Torrey. It differs much in phraseology from that which appeared 57 years later in the Synoptical Flora.

"Somewhat pubescent; stem short; leaves rhombic-ovate, crenately toothed, abruptly narrowed at the base into a petiole; stipules linear-lanceolate, entire, stigma somewhat triangular, emarginate; spur very short; appendages of the inferior stamens wing-form, a little produced at the base.

"California, Douglas.—Lamina of the leaves scarcely an inch long, rather thick, with coarse, obtuse teeth. Peduncles 2-3 times as long as the leaves. Flowers large, deep yellow. Sepals oblong, obtuse. Petals broadly obovate; the two upper ones with conspicuous claws; lateral ones bearded at the base. Summit of the filaments rounded. Stigma with a minute lip on the lower edge."

The species is found abundant from San Francisco Bay to San Diego, Cal., and thence eastward nearly to Arizona. It is highly esteemed for its beauty, often cultivated in gardens, and the flowers are said to be often for sale in the market. This is one of the 25 species that Gray finally accepted as peculiar to North America—13 being east of the Continental Divide and 12 west, viz.:—*V. sarmentosa* Dougl. *V. chrysantha* Hook. *V. Hallii* Gray. *V. glabella* Nutt. *V. pedunculata* Torr. & Gray. *V. Sheltonii* Torr. *V. trinervata* Howell. *V. ocellata* Torr. & Gray. *V. praemorsa* Dougl. *V. Beckwithii* Torr. & Gray. *V. lobata* Benth. *V. cuneata* Watson.

Our color-plate is based on a specimen from South San Francisco collected by Mrs. Viola Brainerd Baird, March, 1916, and painted by Mathews the following May.

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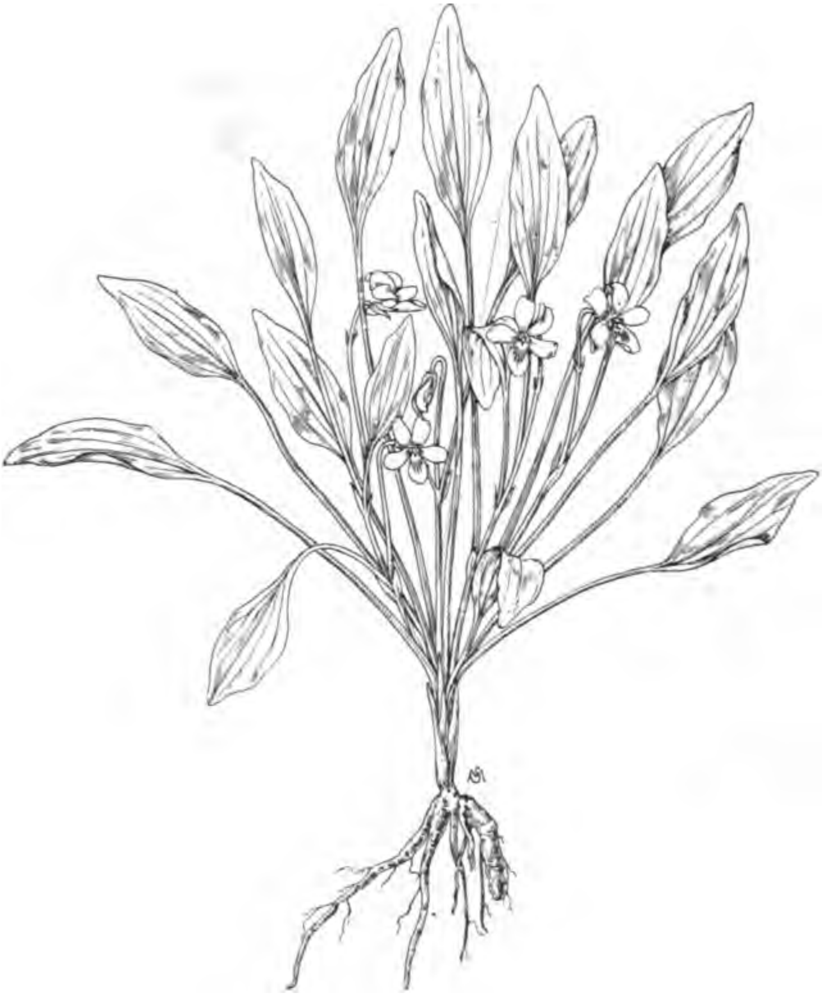
**See color-plate, Species No. 45, opposite page 101.**

**Viola Nuttallii** Pursh, Fl. 1: 174. 1814. Species No. 46.

"On the banks of the Missouri, June, v. s. in Herb. Nuttall."

This species bears the name of a famous student of the natural history of North America from 1808 to 1842. Schweinitz calls him a man of "unsparing zeal." The intense enthusiasm with which he worked sometimes excited the ridicule of his associates. Occasionally he was reckless of danger and prostrate from fatigue or illness. In 1825, his reputation as a naturalist led to his appointment as Curator of the Harvard Botanical Garden, a position he retained until 1834, when his renewed longing for the wild led him to resign and visit for exploration the Pacific Coast. In 1834 he went with the Wyeth expedition across the continent to Oregon. During the winters of 1834-35 and 1835-36, he made two trips to the Hawaiian Islands. In May, 1836, he left San Diego, Cal., on a ship sailing around Cape Horn in a southern winter, and reached Boston the following October. The story of his romantic trip is told in Dana's well-known "Two Years Before the Mast." See also the account of the expedition by John K. Townsend and Captain Wyeth's letters and journals. The next five years Nuttall lived in Philadelphia. In 1838 appeared the first part of Torrey's and Gray's Flora of North America, to which Nuttall contributed numerous descriptions of plants; in 1840 he published extended accounts of new species collected in the United States and the Hawaiian Islands; and in 1841 he wrote his Sylva of North America. On December 25, 1841, he left America to make his home in England, having received the bequest of an estate between Manchester and Liverpool; and here he lived until his death, September 10, 1859, with the exception of the winter of 1847-48, spent in Philadelphia working up for publication the Rocky Mountain plants of Dr. Gambel.



**Species No. 46—Viola Nuttallii Pursh**

There never has been any question as to what plant Pursh described as *V. Nuttallii,* since it was collected by Nuttall in 1811 while with the Astor Expedition on the Missouri River; and Eggleston of the Bureau of Plant Industry, United States Department of Agriculture, to whom we are largely indebted for information, is confident that Nuttall's type came from South Dakota, since on the first of June the Astor party had reached the river on the south line of South Dakota near the present town of Yankton and by the latter part of June had reached the Arickaree village, in Corson County, S. D.

The foliage displays marked fluctuations, some of which have received specific names. *V. linguaefolia* Nutt. is a form with large elongate root-leaves, *V. vallicola* Nelson a form with widened ovate root-leaves.

The color-plate is based on a specimen from Grey Cliff, Mont., altitude 3,904 feet; Eggleston, No. 7871. May 31, 1912.

The line-drawing is made from t. 26, Hooker's Fl. Am. Bor. 1579. 1830.

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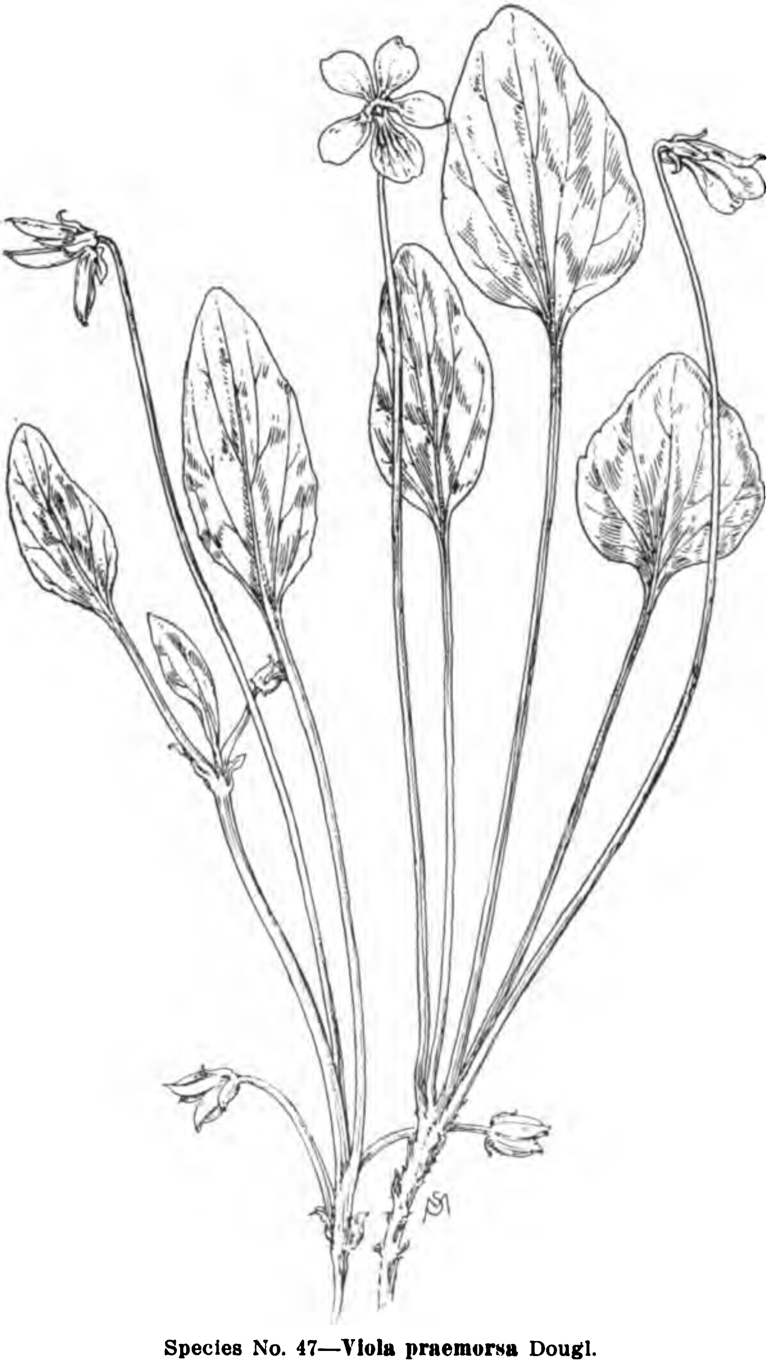
**See also color-plate, Species No. 46, opposite page 101.**



Species No. 47—**Viola praemorsa** Dougl.

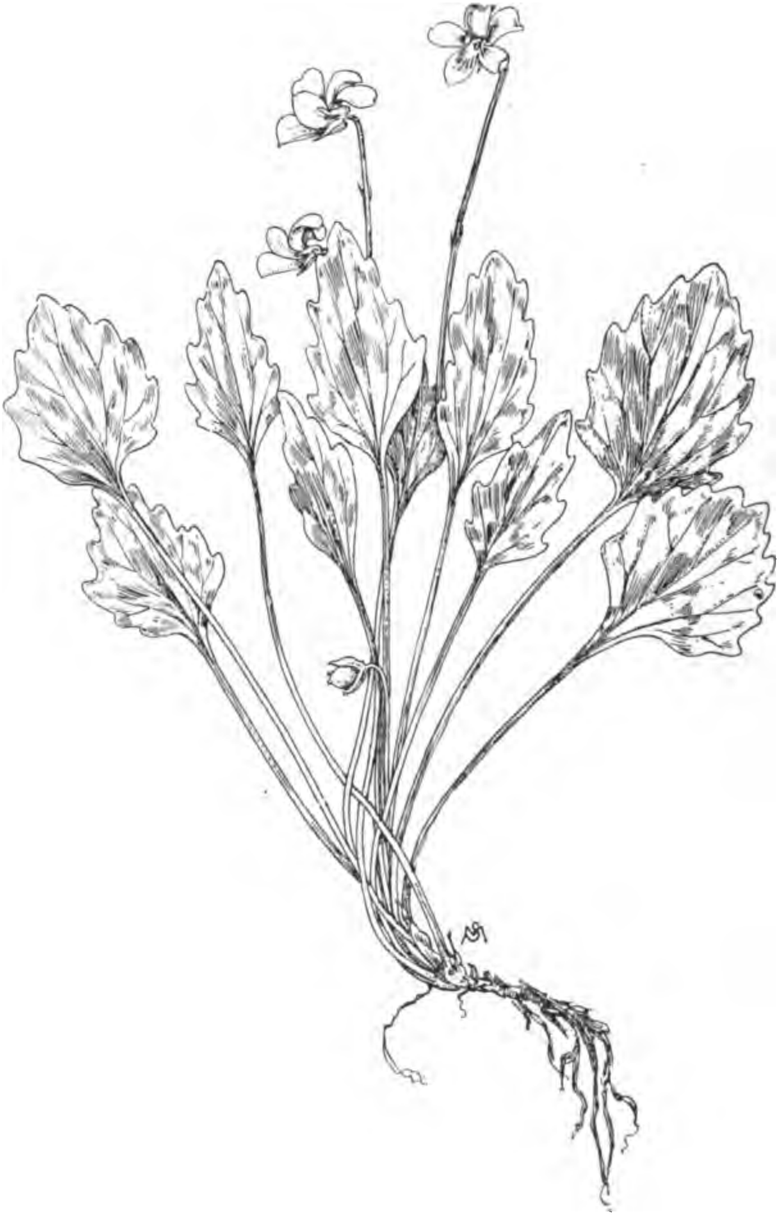
**Viola praemorsa** Dougl. in Lindley's Bot. Register 15, t. 1254. 1829. Species No. 47.

I am greatly indebted to Eggleston for valuable facts regarding the publication of this species, in substance as follows: Lindley's Botanical Register was the organ of the London Horticultural Society, under whose auspices David Douglas explored the botany of the Pacific Coast north of California. In 1914 this Society published an exact copy of his journals. From them we learn that his first violet, *V. praemorsa,* was collected about May 1, 1825, above Astoria on the Columbia River. He secured seeds that were sent by a vessel sailing October, 1825, and reaching England in 1826; from these flowering plants were obtained at least as early as 1828. His specific name, "bitten off" or "truncate," alludes, it is said, to the condition of the rootstocks in the dry, sandy soil where they grew. Lindley tells us in his paper that the drawing for t. 1254 that appeared in the Botanical Register, August 1, 1829, was made in 1828 in the garden of the Horticultural Society. The artist, M. Hart, has figured only that part of the plant that appeared above the soil. It presents a luxuriant specimen having six large flowers, four full-grown and eight small leaves, and the tips of three basal stipules.

The plants in their native soil present an aspect quite unlike that of those raised from seed in England. In the 32 sheets of *V. praemorsa* in the writer's herbarium are to be seen specimens from Vancouver Island, lat. 48½° N., south through Lake County, Ore., and along the Sierra Nevada to the Stanislaus Forest in Tuolumne County, Cal., lat. 38° N. These plants have normally stout, sometimes branching root-stalks, bearing at petaliferous flowering one or more short stems, that, later, elongate and produce an abundance of cleistogamous flowers and seeds.

*V. Bakeri* Greene, Pitt. 3: 307, April, 1898, seems to be a subglabrous, depauperate form of *V. praemorsa* found in the mountains of Oregon and northwestern California.

Our line-drawing is of a specimen collected in the Truckee River Valley, Placer Co., Cal., altitude 7,100 feet, July 5, 1915.



Species No. 48—Viola purpurea Kellogg

**Viola purpurea** Kellogg, Proc. Cal. Acad. 1: 55. May, 1855. Species No. 48.
*V. aurea* Kellogg, Proc. Cal. Acad. 2: 185, t. 54. Sept., 1862.

Both types are described in detail; *V. aurea,* Kellogg states was "brought from Nevada Territory—an alpine species almost woolly in its external appearance." A careful comparison of his descriptions leaves no doubt as to their specific identity.

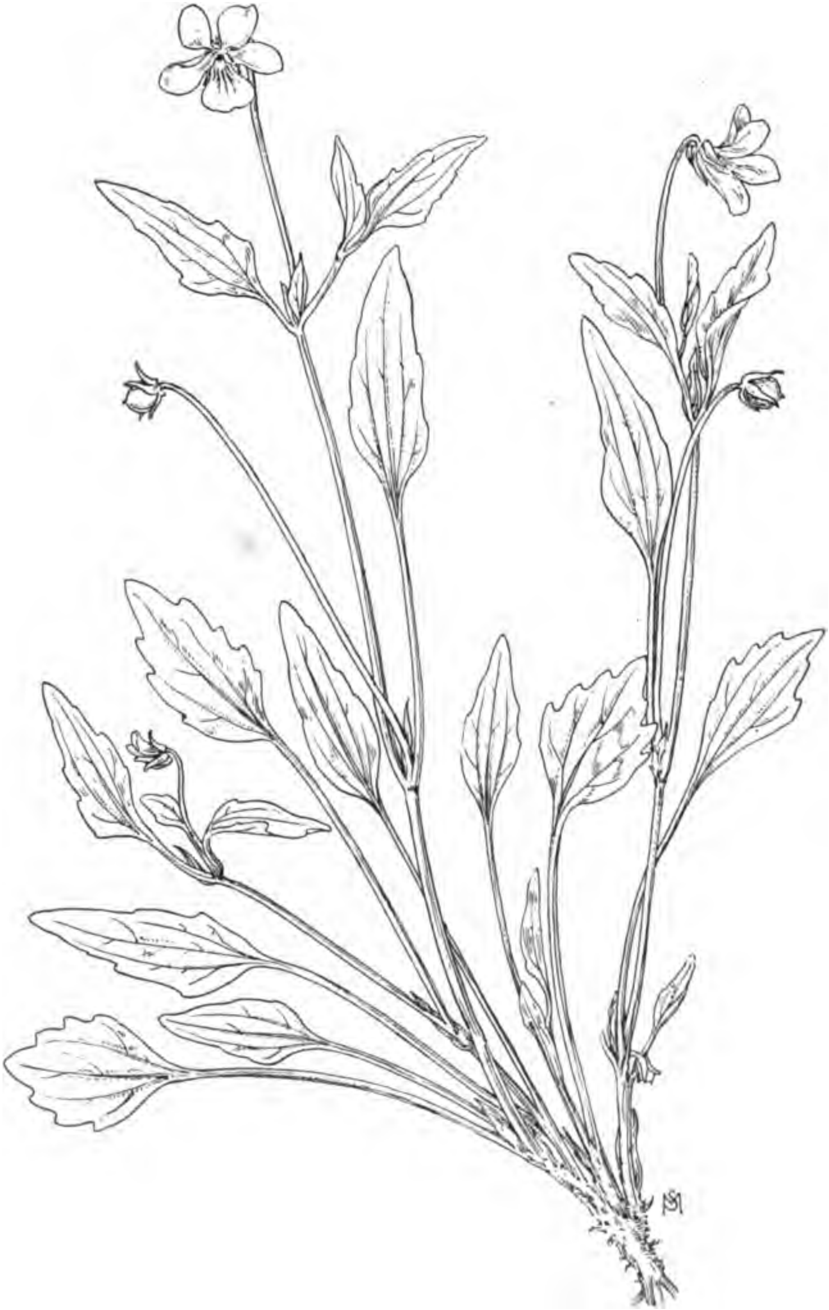
The species is well distributed through California. I have specimens from six counties: along the coast from Santa Barbara, Kern, Santa Cruz, and in the Sierra Nevada from Calaveras, Nevada and Siskiyou. Jepson, in Fl. West. Mid. Cal., ed. 2, p. 266, Jan., 1911, gives the range of *V. purpurea* Kell. as "Coast Range peaks and high mountain ridges: Loma Prieta, Mount Diabalo, Napa and Mount Hood ranges and northward."

Our line-drawing is based on a herbarium specimen from Tehachapi, Kern Co., Cal., Agnes Chase coll., May 6, 1910; but it fails to show the minutely white-villous foliage of the model.

**Viola purpurea** Kellogg, var. **pinetorum** Greene, Fl. Francisc. 243. 1891. See also **V. pinetorum** Greene, Pitt. 2: 14. Nov., 1889.

This variety is abundant in the Lake Tahoe region of Placer County, Cal., and south, where the counties of Tuolumne, Calaveras, Alpine and Eldorado almost corner together. I first collected it near Echo Lake, Eldorado County, July 11, 1897, and in 1915 found it common south of Truckee, Cal.

Our illustration is based on a herbarium specimen from Five Lakes (altitude 7,540 feet), Placer Co., Cal., Mrs. Viola Brainerd Baird and E. Brainerd, coll., July 15, 1915.



Species No. 48b—**Viola purpurea** Kellogg var. **pinetorum** Greene

**Viola purpurea** Kellogg, var. **venosa** (Wats.) comb. nov.
*V. Nuttallii,* var. *venosa* Watson, Bot. King Exped. 35. 1871.
*V. aurea,* var. *venosa* Brewer & Watson, Bot. Cal. 1: 56. 1876.
*V. atriplicifolia* Greene, Pitt. 3. 38. May, 1896.
*V. Thorii* Nelson, Bull. Torr. Cl. 27: 193. 1900.
*V. venosa* (Wats.) Piper, Contrib. U. S. Hb. 11: 393. 1906.
*V. atriplicifolia Thorii* Nels., Coulter's Man. 321. 1909.

Watson's original collection was made in the mountains of northwest Nevada, "from the West Humboldt to the Watsatch usually near the snow line." I have a specimen[1] from Plumas County, Cal., quite like one of Watson's types.

The above synonymy indicates a wide distribution of this variety, but a careful study of the specimens shows a marked sameness of character except in the contour of the root-leaves, that vary all the way from nearly entire to coarsely dentate or shallowly lobed; and these forms occur sometimes in the same locality. This has made it difficult for authors to determine to what species the variety should be attached, if, indeed, it should not bear a specific name of its own. To me, its affinity seems nearest to *V. purpurea* Kellogg, in the neighborhood of which it is frequently found in Nevada, California and Oregon.

The line-drawing is of a plant from "The Craggs" (altitude 8,250 feet), Deer Park, Placer Co., Cal., Brainerd, coll., July 19, 1915.

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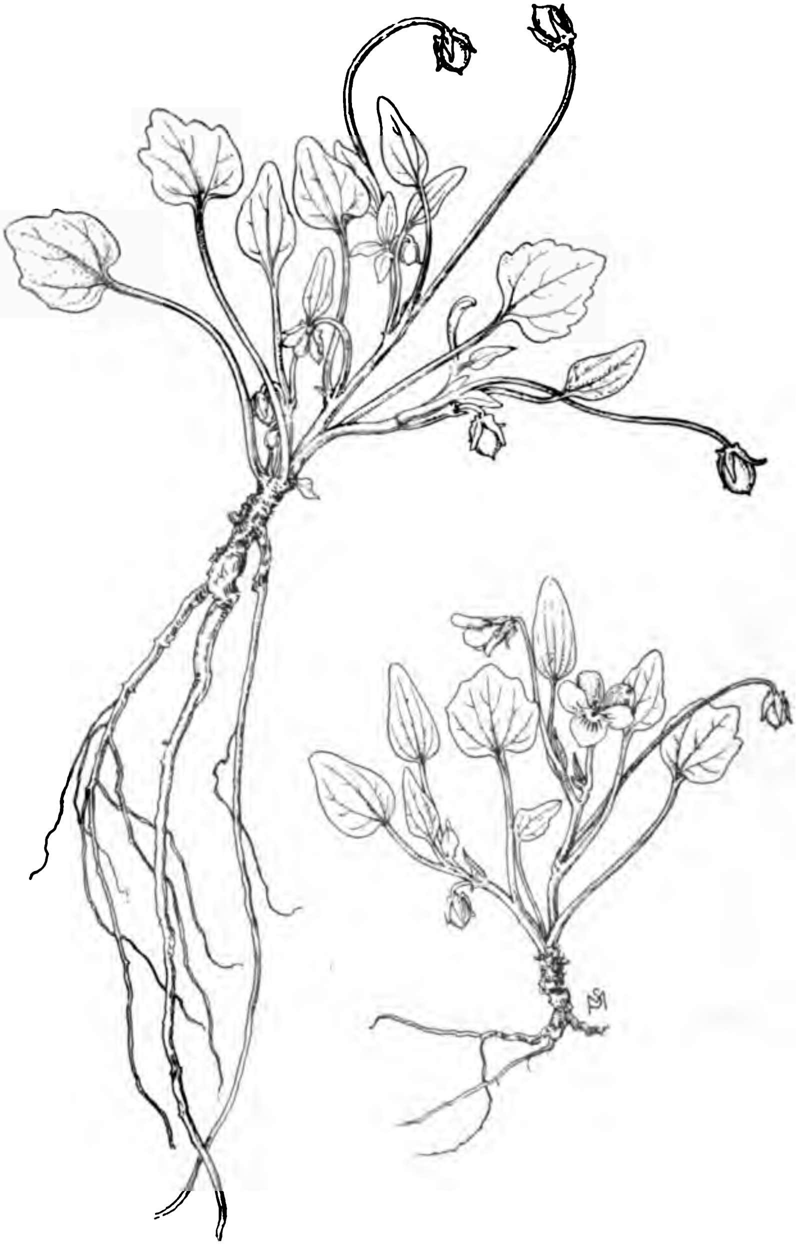
[1] Mrs. Austin, coll., 1877. C. G. Pringle, donor.



Species No. 48c—**Viola purpurea** Kellogg var. **venosa** (Wats.)

**Viola chrysantha** Hooker, Icones Plantarum, t. 49. 1837. Species No. 49.

The description of Hooker and the accompanying plate are in many respects faulty, apparently due to defects in the type specimen or to its receiving some later injury. A more complete diagnosis was given a year later in Torrey and Gray's Flora 1: 143, 1838, where the lower petal is correctly described as "slightly saccate at the base."

The type of Douglas was collected at Monterey, lat. 36½° N. on the coast of California. The fine color-plate here presented is from a painting by Mathews, based on a dried plant collected at Big Bear Lake, altitude 7,200 feet, near the city of San Bernardino, Cal., May 26, 1917, G. D. LaMotte, coll.

This violet. seems not to be abundant in any one locality, but has been collected in about 10 different counties, as appears by mounted specimens in the University Herbarium at Berkeley, Cal. The writer has a flowering specimen from Plumas County, collected by Mrs. Ames, 1876, and one from Shasta County, Alice Eastwood, June and July, 1912. Howell reports it from Medford, Ore., 21 miles north of the California line. Probably many other stations will be found from time to time in this large state extending through nine degrees of latitude, a distance of 600 miles. The map shows that a state the length of California, if laid out on the Atlantic Coast would reach from New York City as far south as Savannah, Ga.

*V. chrysantha* was most appropriately called by the elder Hooker the "golden flower," and may justly be classed with *V. pedunculata, V. Hallii* and *V. cuneata* as one of the most beautiful violets of the Pacific coast.

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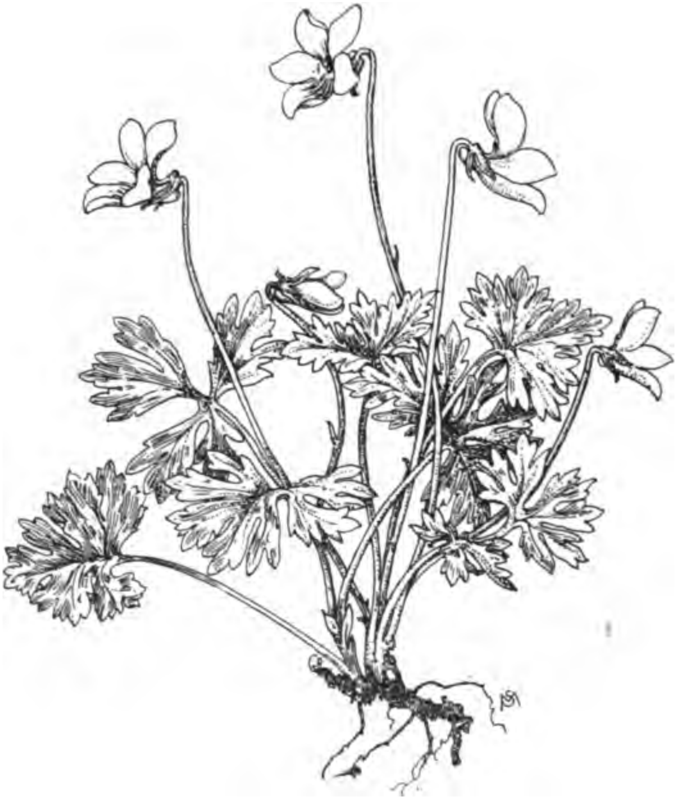
**See color-plate, Species No. 49, opposite page 132.**



Species No. 50—**Viola Sheltonii** Torr.

**Viola Sheltonii** Torr. in Whipple Survey 35th Parallel, Pacif. R. R. report 4: 67, t. 2. 1856. Species No. 50.

Five localities are given for this species in the Synop. Fl., namely, Colusa, Lake and Plumas Counties, Cal., southern Oregon and White Salmon Valley, Wash. In 1913, Eggleston collected it in Calaveras County, and in 1912, Miss Eastwood in Placer County, Cal. In Torrey's original publication only the type station is cited, "hillsides, Yuba, near Downieville, May 8 (1854, Dr. J. M. Bigelow)," Sierra Co., Cal.

*V. biternata* Greene[1] is to me not distinct from *V. Sheltonii* except as growing much farther east. I have a leaf of Greene's type which is a good match for those of *V. Sheltonii.* The types of *V. biternata* are C. F. Baker's No. 42, from Cerro, Colo., and No. 233, from Grand Mesa, Colo., June, 1901.

These scattered stations stretching for over 575 miles north and south will probably in time be connected with scores of others.

Our line-drawing is a copy of the illustration "t. 2" that appeared with Torrey's original report in 1856.

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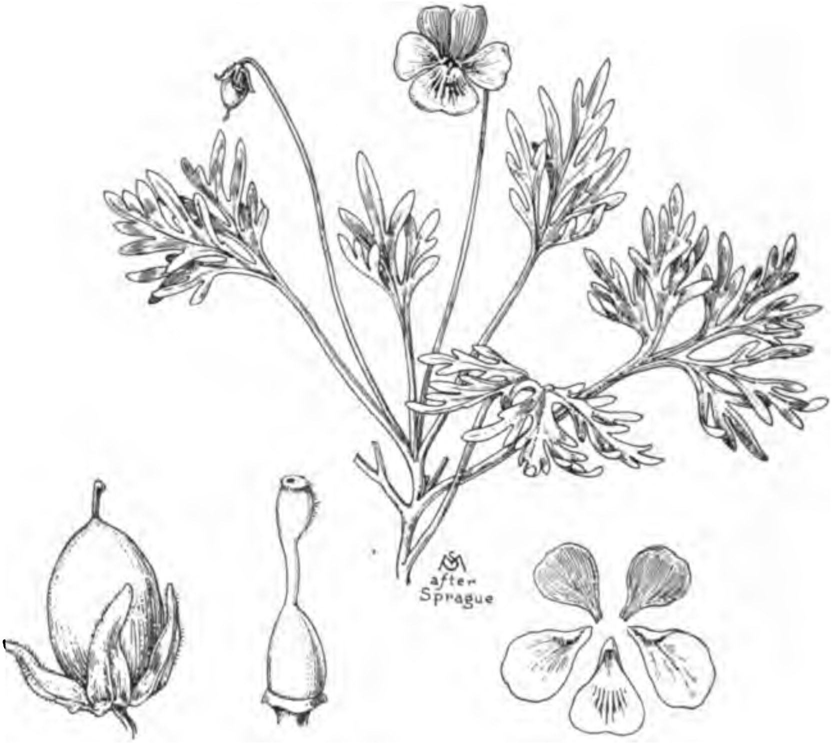
[1] Plantae Bakeri, 3: 12. Nov., 1901.



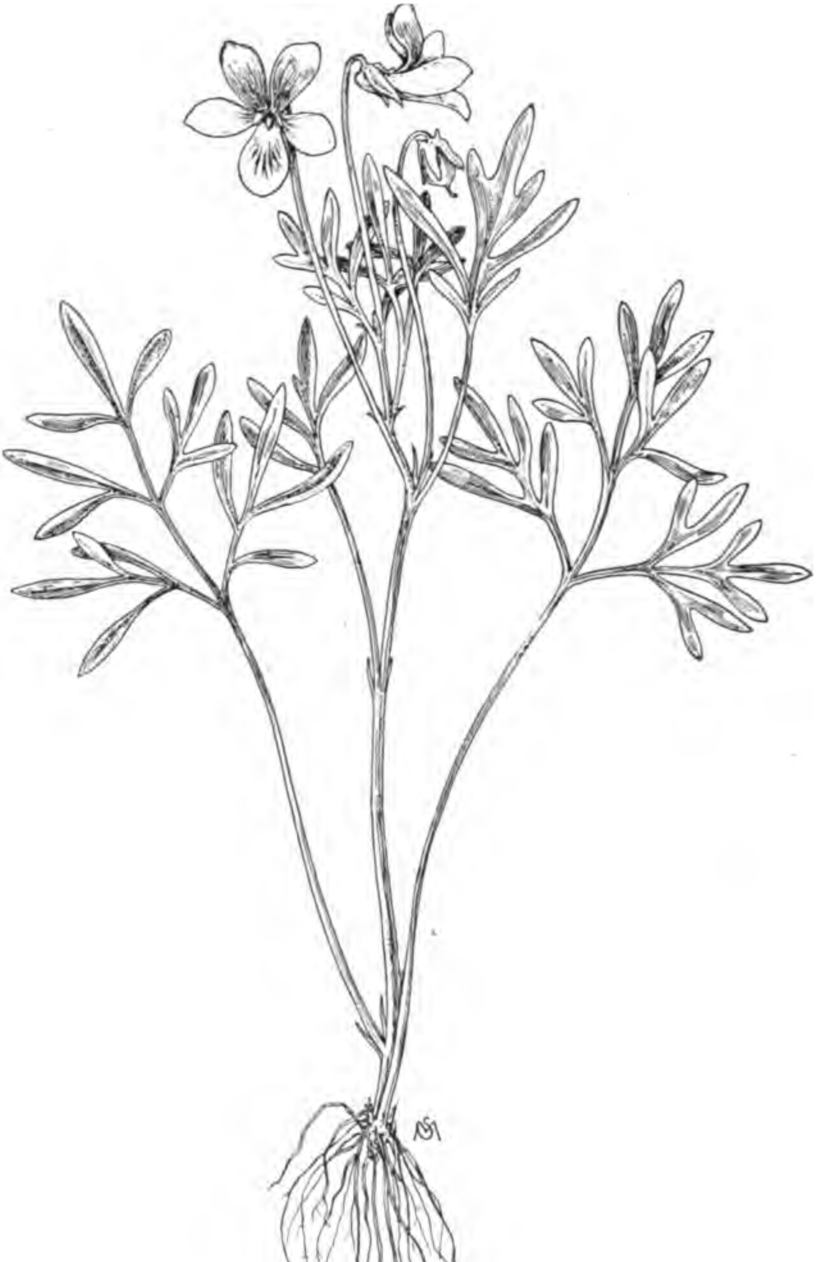
Species No. 51—**Viola Beckwithii** Torr.

**Viola Beckwithii** Torr. & Gray in Beckwith Survey 41st Parallel, Pacific R. R. report 2: 119, t. 1. 1855. Species No. 51.

The type came from Diamond Mountain, Eureka Co., Nev., "between Great Salt Lake and the Sierra Nevada." I have a specimen, given me by Coulter, collected by Mrs. R. M. Austin at Plumas County, Cal., about 250 miles west of the type station; one from Golconda, Humboldt Co., Nev., about 50 miles northwest of the type station; and a third from Salt Lake City, Utah, A. O. Garrett, coll., April 19, 1912. But most helpful of all is a large collection from Verdi, Nev., almost on the Californian border, 20 miles north of Lake Tahoe, made April 1, 1921, and sent me well preserved by Mrs. Viola Brainerd Baird. These specimens are quite hirsute as in the type, and reveal a flower that may be thus described: Upper petals dark violet; lateral petals lilac to white, the base yellow and bearded; spur petal longer, lilac, the yellow base marked with 7-9 purple striae, but plants occur with spur petal varying to white.

Torrey, in his account of *V. Sheltonii,* 1856, casually speaks of the two upper petals of *V. Beckwithii* as "purple," and in the original report of 1855, Torrey and Gray call them "deep-violet." These two terms are in substantial agreement with "dark violet."

The line-drawing is an exact copy of Isaac Sprague's t. 1. 1855.



Species No. 52—Viola Hallii Gray

**Viola Hallii** Gray, Proc. Am. Acad. 8: 377. 1872. Species No. 52.

This is one of the rarest of the 25 North American violets selected for our color-plates, and among the latest to receive recognition. It was originally published in Gray's report of the plants collected by Elihu Hall in Oregon. Fourteen years later in his revision of North American violets[1] he redescribed it as follows:—"Glabrous throughout; the leaves of ovate or oblong or of irregular outline, sub-pinnately or pedately about twice parted into lanceolate or linear lobes, their tips obtuse or acutish and callous apiculate, veins or ribs indistinct; upper stipules commonly foliaceous, often enlarged and laciniate or entire; upper petals deep blue, others yellow or cream-color. From Salem, Ore., to Humboldt County, Cal. More caulescent than the preceding."—*V. chrysantha, V. Beckwithii, V. Sheltonii.*

To this should be added Dr. Hall's description of the living plant:[2] "Two upper petals dark, velvety purple, almost black, lowest petal white with yellow-veined base, lateral petals same color with short, hairy patch on claws." This indicates a flower much like that of *V. cuneata,* see color-plate species No. 64. In the Synoptical Flora the term "violet-purple" is used for the upper petals of both species.

The rare occurrence of *V. Hallii* is indicated by the fact that it is now represented in the Herbarium of the University of California by only three mounted specimens, viz.:

1. Salmon Mountains, Parker Co. and Trinity Co., Cal., July.
2. Kneeland Prairie, Humboldt Co., Cal., May.
3. Buck Mountain, Humboldt Co., Cal., altitude 5,000 feet, June.

"Near the summit, frequent in gravelly, open spots in the chapparal."

The color-plate is of a water-color by Mathews (May, 1918), based on a specimen in the Gray Herbarium from Grant's Pass, Ore., the color after description in the Synoptical Flora, "Petals strongly two-colored, lateral and lower yellow or cream-color."

The line-drawing is from the same specimen, with added roots.

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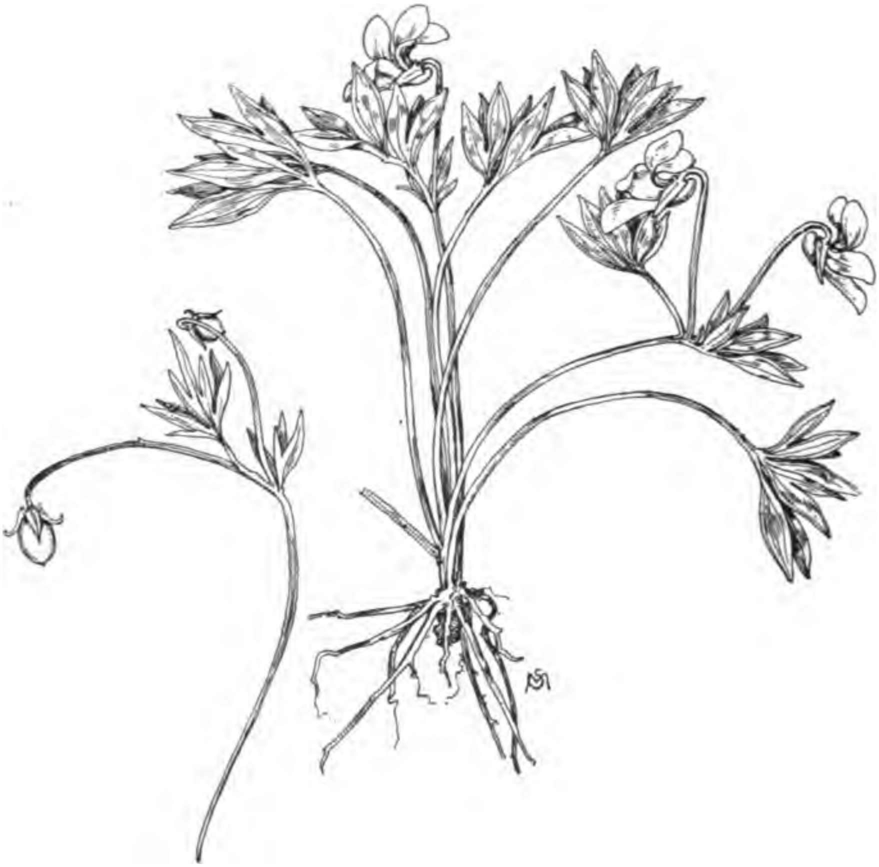
[1] Bot. Gaz. 11: 253-6. Nov., 1886.

[2] In letter from Mrs. Viola Brainerd Baird, Berkeley, Cal.

**See also color-plate, Species No. 52, opposite page 132.**



**Species No. 53—Viola trinervata Howell**

**Viola trinervata** Howell, Gray in Bot. Gaz. 11: 290. Nov., 1886. Species No. 53.

*V. chrysantha* var. *glaberima* Torr., Bot. Wilkes Exped. 238. 1874.
*V. Beckwithii* var. *trinervata* Howell, Bot. Gaz. 8: 207. 1883.

Through the kindness of Mr. W. R. Maxon, Associate Curator of the National Museum, I have been able to examine seven sheets of this rare species as described in the following table:

| *Station* | *Lat.* | *Collector* | *Date of Collection* | *Number in National Herbarium* |
|---|---|---|---|---|
| Interior of Washington Territory | | Wilkes Exploring Expedition, No. 1106. | 1841. | 7474 |
| Klickitat County, Wash. | 45° 54′ | Thomas Howell. | April, 1882 "Ex herb. Wm. M. Canby." | 7476 |
| North Yakima, Wash. | 46° 38′ | From Frittillaria Club, 1890. | | 7475 |
| Juniper Springs, Malheur Co., Ore., Alt. 4,335 feet. | | John B. Leiberg, 2280. | June 15, 1896. | 276 193 |
| Hill near Ellensburg, Wash. | 47° | Kirk Whited, No. 606. | April 8, 1898, in fl. | 366 336 |
| Mount Rainier Forest Reserve, Wash. | 46° 55′ | J. B. Fleet. | June 5, 1899. | 415 548 |
| Stehekin, eastern Washington. | 48° 16′ | David Griffiths & J. S. Cotton. | June, 1902, in fl. | 527 524 |

The color of the petals may be learned fairly well from the notes of collectors or from the dried specimens. In the Bot. Gaz., 1886, Gray quotes Torrey as saying in his 1874 paper that "the upper petals are purplish and the others yellow (doubtless from Pickering's notes)." Howell in his Flora of northwest America, March, 1897, says "upper petals dark blue, the others pale blue with a yellow base." This probably is a not infrequent misuse of the word "blue" for "violet," as we commonly speak of "the blue violets," avoiding the correct but awkward term "violet violets."

In specimen No. 7475 National Herbarium the upper petals are plainly dark violet as in *V. Beckwithii,* and one spur-petal has nine striae on its lower half. The upper dark petals are to be seen also on specimens No. 366 336 and No. 527 524 Nat'l Hb.

Our line-drawing is from specimen No. 7476 Nat'l Hb., T. Howell, coll., April, 1882, "ex herb. Wm. M. Canby."

**V. hastata** Michx., Bor. Am. 2: 149. 1803. Species No. 54.

The species was well described by Michaux, and also nine years later by Pursh. LeConte, 1826, for reasons that will appear later, regarded *V. tripartita* Ell. as a variety of *V. hastata,* and Gray 40 years afterward endorsed this opinion.[1] But there is a radical difference between the two. The rootstock of *V. hastata* is brittle, whitish, and has capillary roots; that of *V. tripartita* is woody, brown, and has coarse, fibrous roots. A comparison of the color-plate of the former with the line-drawing No. 56 of the latter reveals their specific unlikeness, both in foliage and rootstock.

But *V. tripartita* is closely associated with a form having uncut leaves: *V. hastata* var. *glaberrima* Gingins in DeCandolle's Prodromus 1: 300. 1824. This was published in 1900 as *V. tripartita* var. *glaberrima* (Gingins) Harper,[2] a plant often found in the vicinity of Biltmore and Tryon, N. C., and as far southwest as Tuscaloosa, Ala. The writer has visited these stations and found Elliott's species and Harper's variety of it to be often associated and intergrading. The habitat is that well described by LeConte—"dark forests and ravines where the soil is enriched by dead leaves and rotten wood." He speaks of its close relationship to *V. pubescens,* so that it may be doubted if the two are distinct. Two of his water-colors well represent *V. tripartita* Ell. and Harper's intergrading variety.

But it is evident in the light of recent discoveries that we have here a case of dimorphism where a species and its variety for successive generations interbreed. This we have seen occurs with *V. Brittoniana* and *V. pectinata,* also in *V. lobata* of the West and its variety *integrifolia* Watson; and in other genera than *Viola.* A noted example is *Phaseolus multiflorus,* an American species with scarlet flowers and seeds, but interbreeding even in the wild with an albino variety.

*V. hastata* is found from Pennsylvania and Ohio south to Liberty County, Fla., about 30 miles southwest of Tallahassee, usually in rich woodlands. Our color-plate is based on a herbarium specimen from Tryon, N. C., Brainerd, coll., April 7, 1909. See also Nos. 62 and 63 of my Distribution of Eastern North American Violets, 1910.

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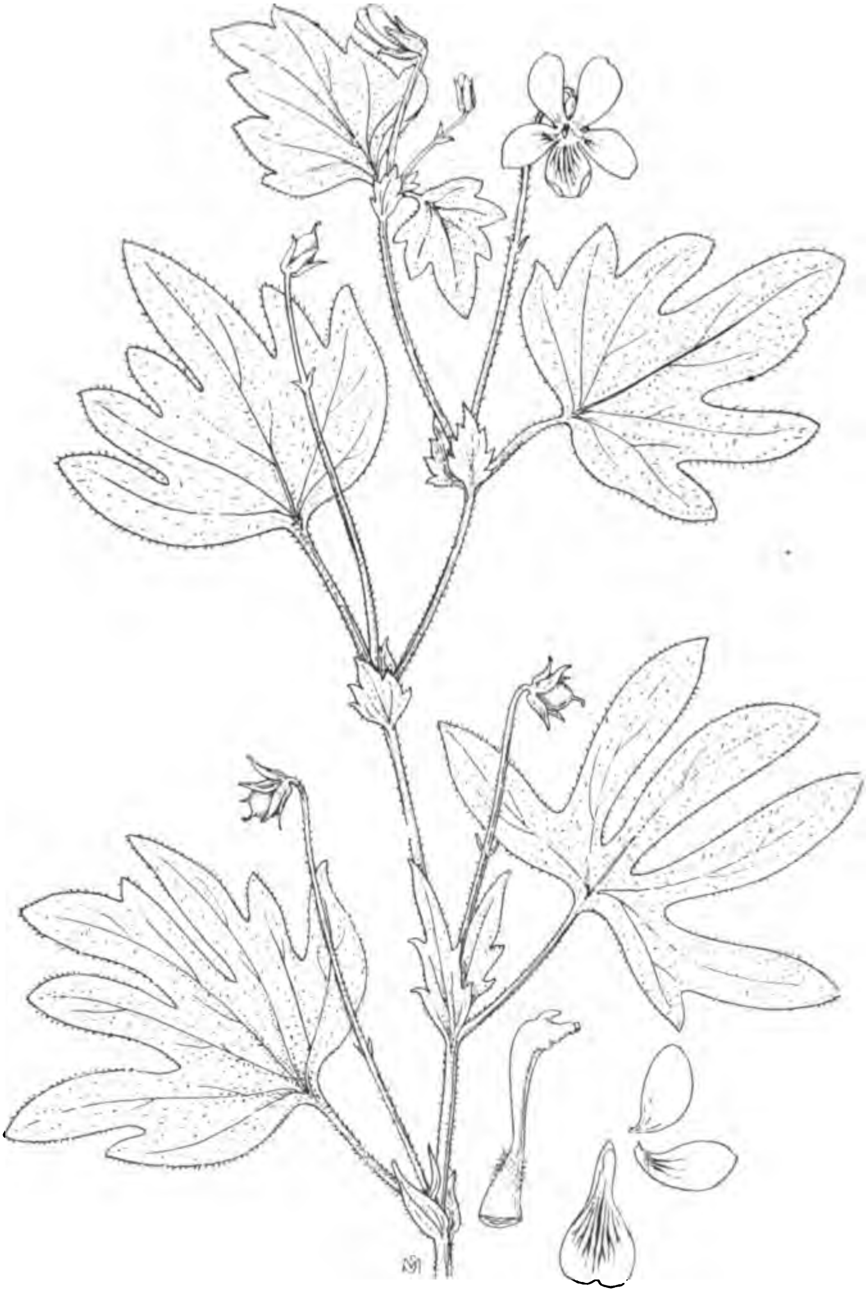
[1] Bot. Gaz. 11: 291. Nov., 1886.
[2] Bull. Torr. Bot. Club 27: 337.
**See color-plate, Species No. 54, opposite page 132.**



Species No. 55—**Viola lobata** Benth.

**Viola lobata** Benth., Pl. Hartweg. 298. Species No. 55.

This species is almost confined to California. Its range is from the Yosemite Valley north to Nevada City, thence north to the contiguous counties Plumas, Butte and Siskiyou, and four miles north of California to Siskiyou, Ore.

The synonym *V. sequoiensis* Kellogg[1] came from Nevada City, Nevada County. Mrs. Baird and I visited the station July 31, 1915, and collected numerous specimens—all typical *V. lobata.* The supposed Sequoias proved to be firs.

The dimorphism of *V. lobata* and its var. *integrifolia* Watson[2] is discussed under *V. hastata* Michx., sp. No. 54; see also under *V. tripartita* Ell., sp. No. 56. It is gratifying to know that Dr. Gray[3] fully recognized the confluence of *V. lobata* with its digitately cleft or lobed leaves, and its very distinct variety "with mostly deltoid or rhombic-ovate, often caudate-acuminate leaves."

Our line-drawing is a reproduction of fig. 55, *V. sequoiensis* Kellogg.

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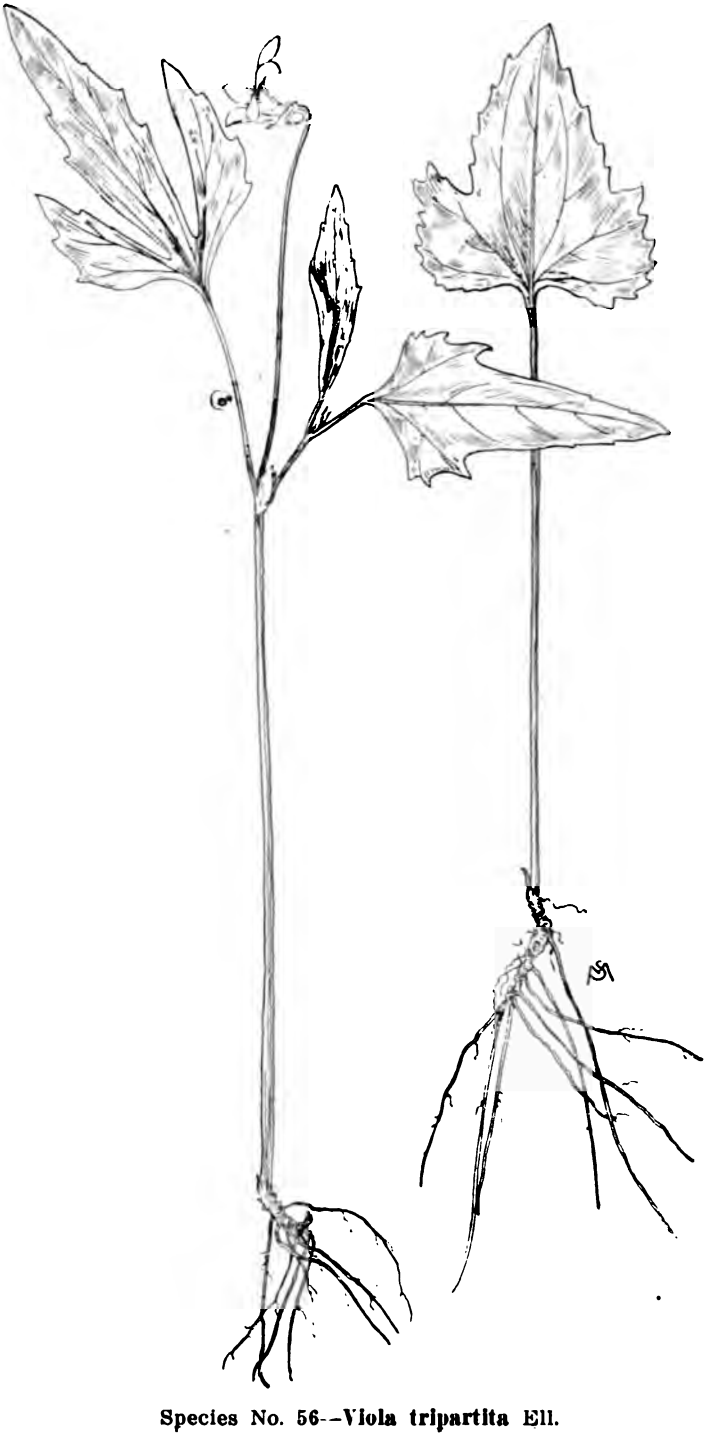
[1] **Proc. Cal. Acad. 2: 185, fig. 55. 1863.**

[2] ***V. Brooksii*** **Kellogg. Cal. Hort. 9: 281. 1879.**

[3] **Bot. Gaz. 11: 290. Nov., 1886.**



**Species No. 56--Viola tripartita Ell.**

**Viola tripartita** Ell., Bot. S. C. & Ga. 1:302. 1817. Species No. 56.

The type of Elliott's species came from near Athens, Jackson Co., Ga., but the species is best developed in the western mountains of the Carolinas. Its botanical history is connected with a plant having uncut foliage usually growing with it. This was first described by Schweinitz[1] as "*V. striata* LeConte and Nobis. Non *V. striata* auctorum." His description is detailed and exact and the plant can be positively identified. Two years later it appeared as *V. hastata* var. *glaberrima* DC., Prodr. 1: 300. 1824.

In 1826, LeConte in his monograph of Viola[2] held the plant to be doubtfully distinct from *V. pubescens* Ait., but published both this and *V. tripartita* as varieties 1 and 2 of *V. hastata.* Two of his extant water-colors are: (1) Typical *V. tripartita;* (2) a plant somewhat resembling *V. pubescens* Ait. in foliage, but not in pubescence nor in cordate leaf. In 1900 the latter plant was renamed[3] *V. tripartita* Ell. var. *glaberrima* (Ging.) Harper.

With the new century, material accumulated rapidly. Many specimens were distributed from Biltmore, N. C., by Pollard, by Eggleston, and from Oconee County, S. C., by H. D. House. In April, 1909 and in 1910, I visited the stations in Biltmore and Tryon, N. C., and in Tuscaloosa, Ala., and found the uncut-leaved variety usually growing with *V. tripartita* and variously intergrading with it. See Nos. 173 and 174 of Distribution, 1910, for these two forms.

As already stated under *V. hastata,* sp. No. 54, we have here evidently a case of dimorphism, where a species repeatedly interbreeds with its variety and the crossing is followed by Mendelian reversion.

The line-drawing is of a specimen from Biltmore, N. C., April 20, 1910.

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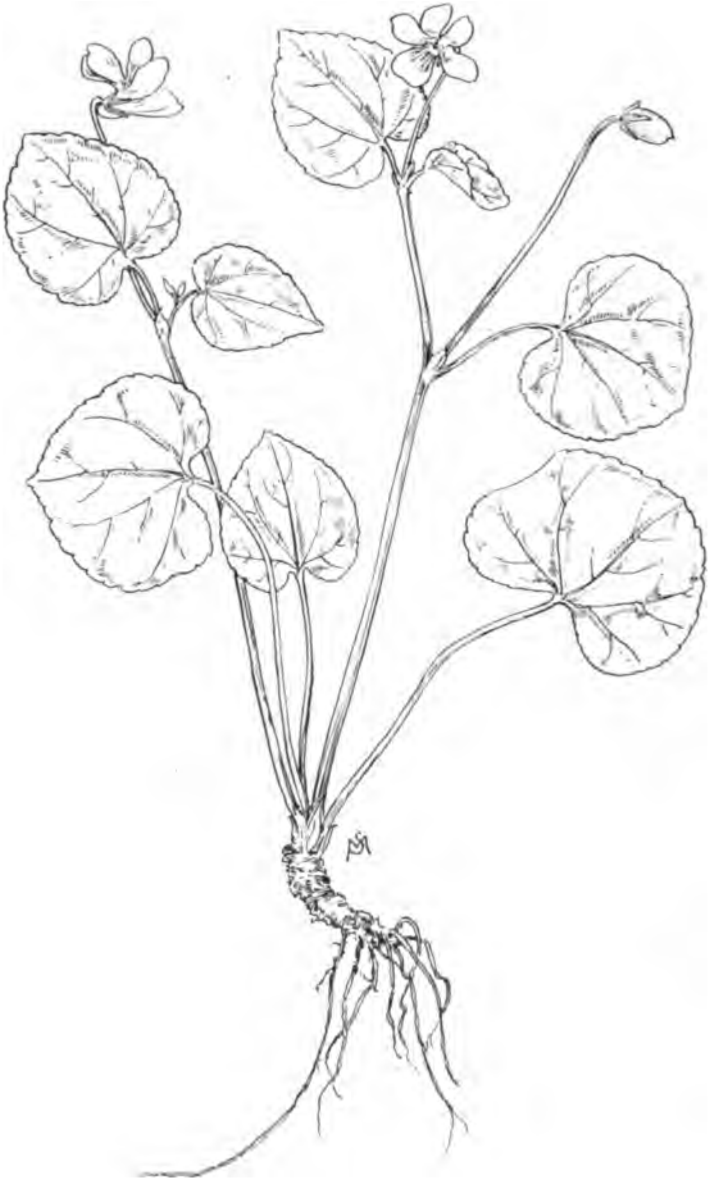
[1] Am. Jour. Sci. 5: 76. April, 1822.
[2] Ann. Lyc. N. Y. 2: 151. 1826.
[3] Bull. Torr. Cl. 27: 337. 1900.



Species No. 57—**Viola glabella** Nutt.

**Viola glabella** Nutt. in Torr. & Gray Fl. 1: 142. 1838. Species No. 57.

Gray[1] states that this is "a Pacific species ranging from the middle parts of California to Alaska and to Japan; its northernmost forms coming too near the Asiatic, *V. uniflora* L., while its most eastern in the northern Rocky Mountains are not easily distinguished from *V. pubescens*."

The most northern station represented in my herbarium is Prince Rupert, B. C., lat. 54° N.; thence it ranges south in two different lines, one near the coast, often at sea-level, to Marin County, Cal., the other more inland through Salem, Ore., and along the Sierra Nevada, at altitudes from 3,500 to 7,500 feet, to the Yosemite Valley, Cal., lat. 38° N. All these stations are congenial to this Alaskan species, as they have about the same low temperature, due to the northern currents of the ocean on the east and to the snows of the Sierra Nevada on the west.

A few stations for *V. glabella* occur in northeastern Washington, northern Idaho and Montana; but *V. pubescens* and *V. eriocarpa,* the nearest of kin, though markedly different, occur only 800 miles to the east.

Our line-drawing is of a herbarium specimen from Five Lakes (altitude 7,540 feet), Placer Co., Cal., coll., Mrs. Viola Brainerd Baird and E. Brainerd, July 15, 1915.

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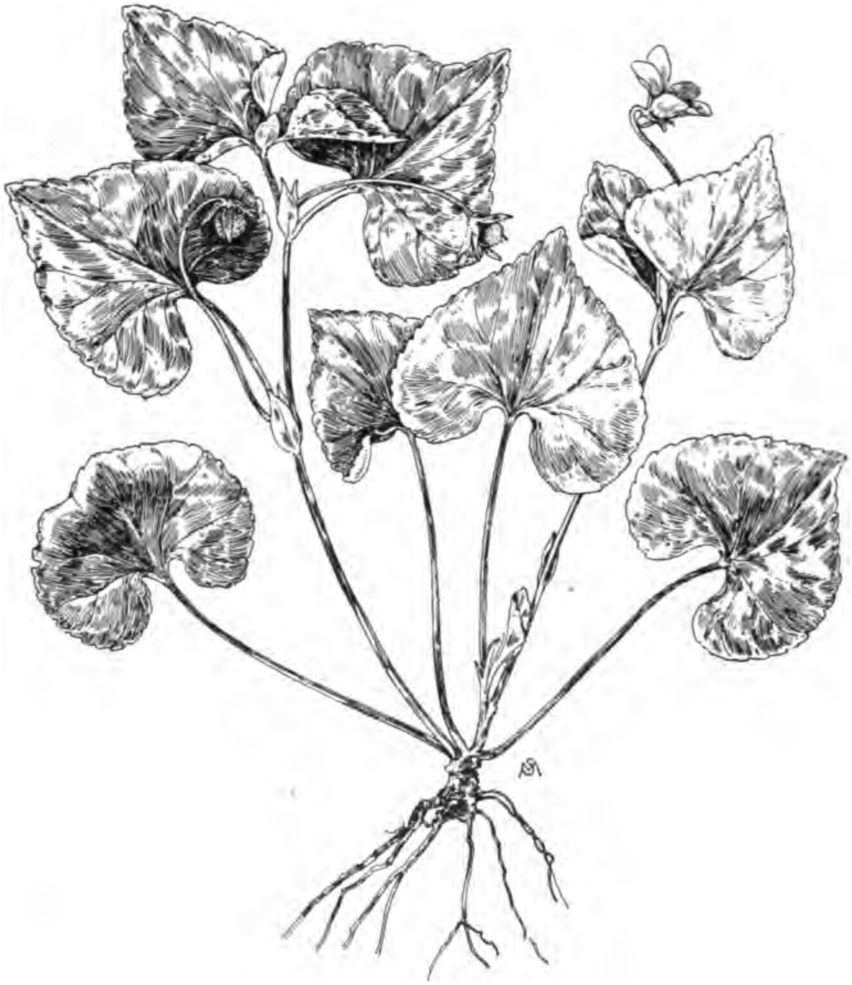
[1] Bot. Gaz. 11: 291. Nov., 1886.



**Species No. 58—Viola eriocarpa Schwein.**

**Viola eriocarpa** Schwein., Am. Jour. Sci. 5: 75. 1822. Species No.
**Viola pubescens** Ait., Hort. Kew. 3: 290. 1789. Species No. 59.
58.

These two species are best discussed together. The line-drawings show their marked unlikeness when isolated from each other. But when growing together their characters are more or less commingled. We have discussed a similar confluence of *V. fimbriatula, V. emarginata* and *V. sagittata.* For this exchange of characters between two allied species DeVries[1] coined the word "vicinism."

The most characteristic *V. pubescens* is found from lat. 40° to 49° N., between Nova Scotia and the Dakotas; farther south it occurs mainly in the Appalachian Mountains. Schweinitz says it is never met with in Salem, N. C. Typical *V. eriocarpa* is found from lat. 35° to 36½° between western North Carolina and northeastern Oklahoma. Schweinitz devotes a whole page to the description of *V. eriocarpa,* tabulating a dozen points of distinction. An additional mark of difference is the coarseness or fineness of the dentation. Usually the stem-leaf of *V. eriocarpa* has 25 to 30 teeth, that of *V. pubescens,* 30 to 45.

In connection with this description, note line-drawing on both pages 130 and 132.

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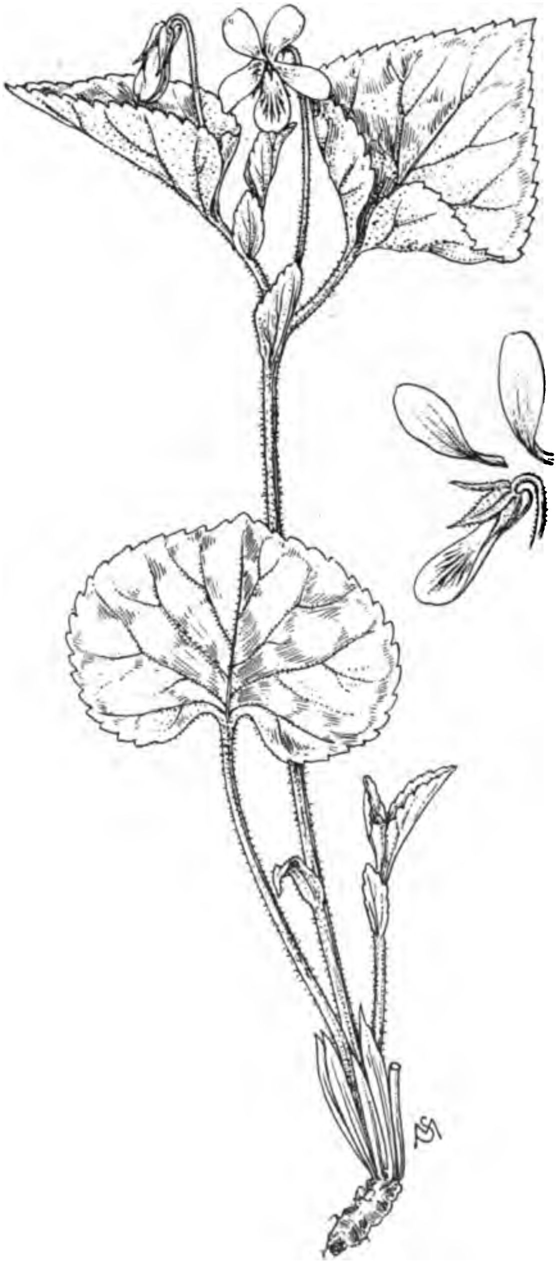
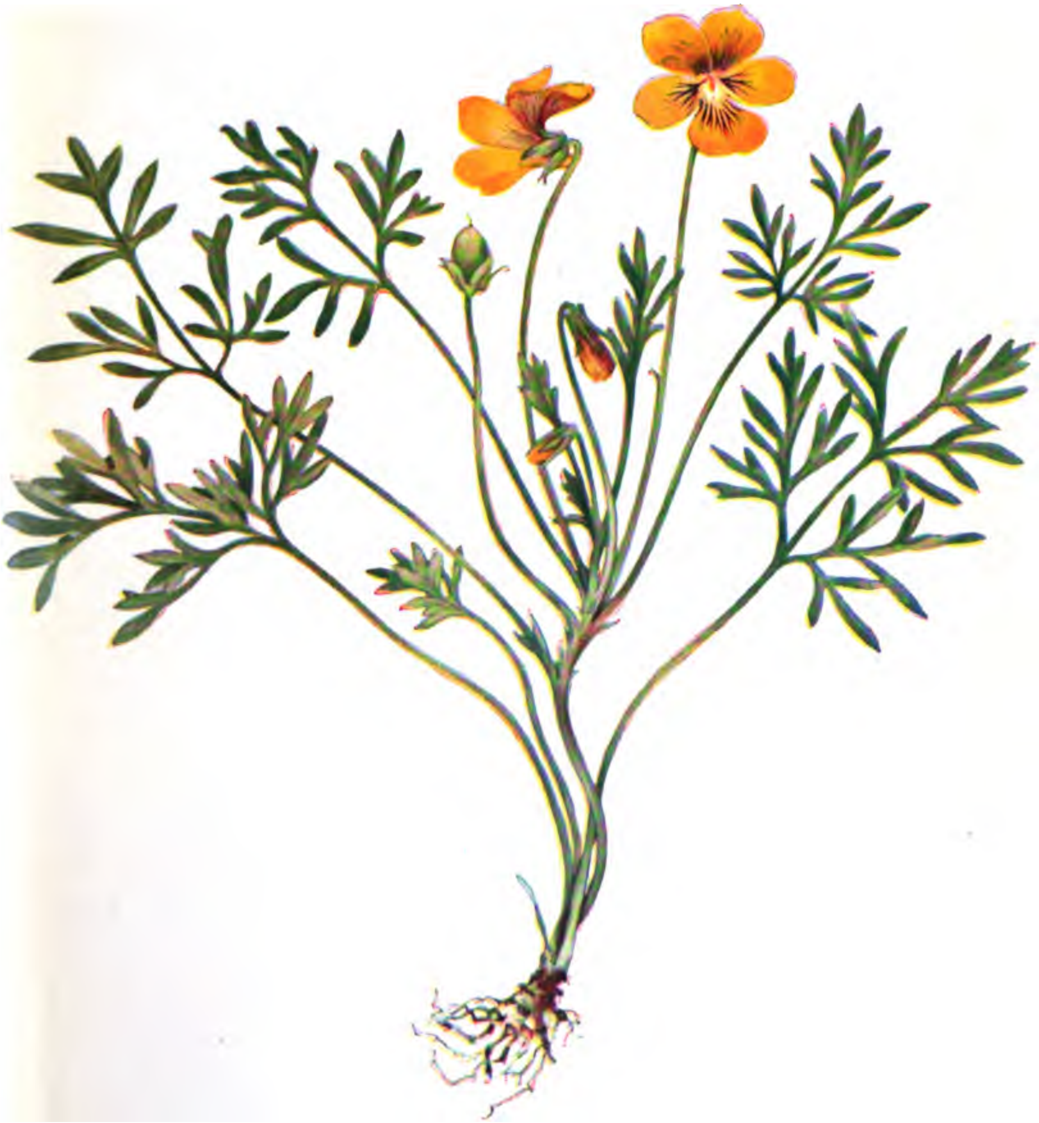
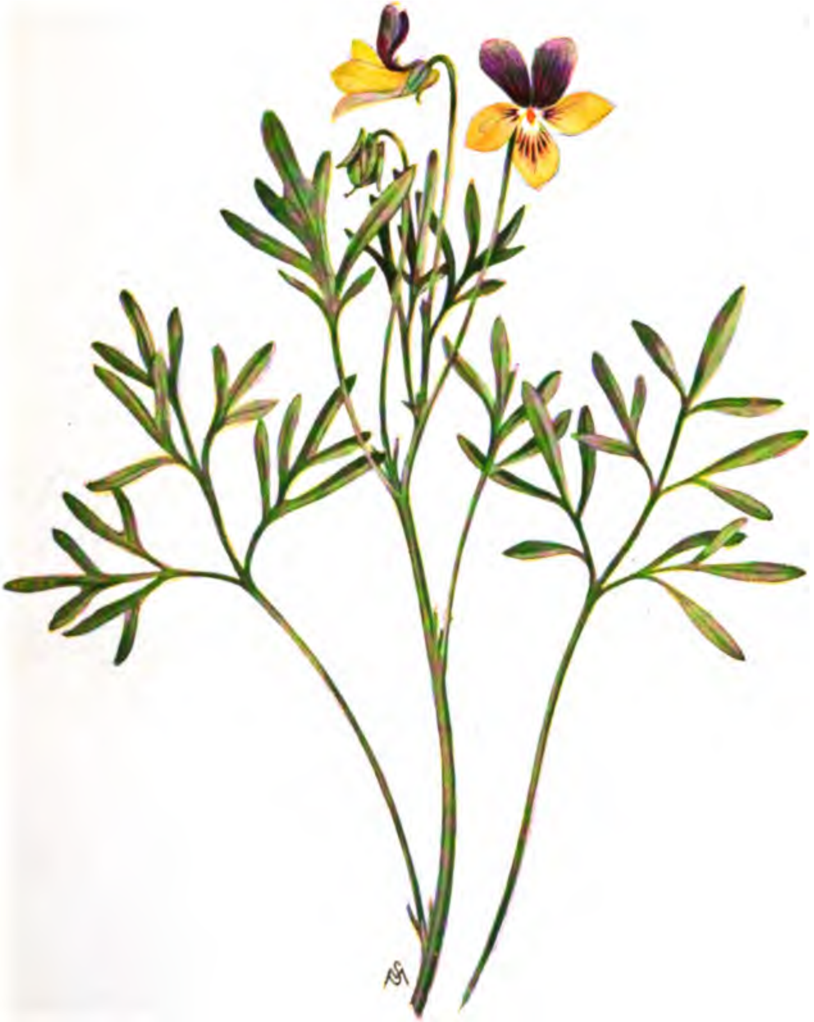
[1] Species and Varieties, p. 188. 1904.



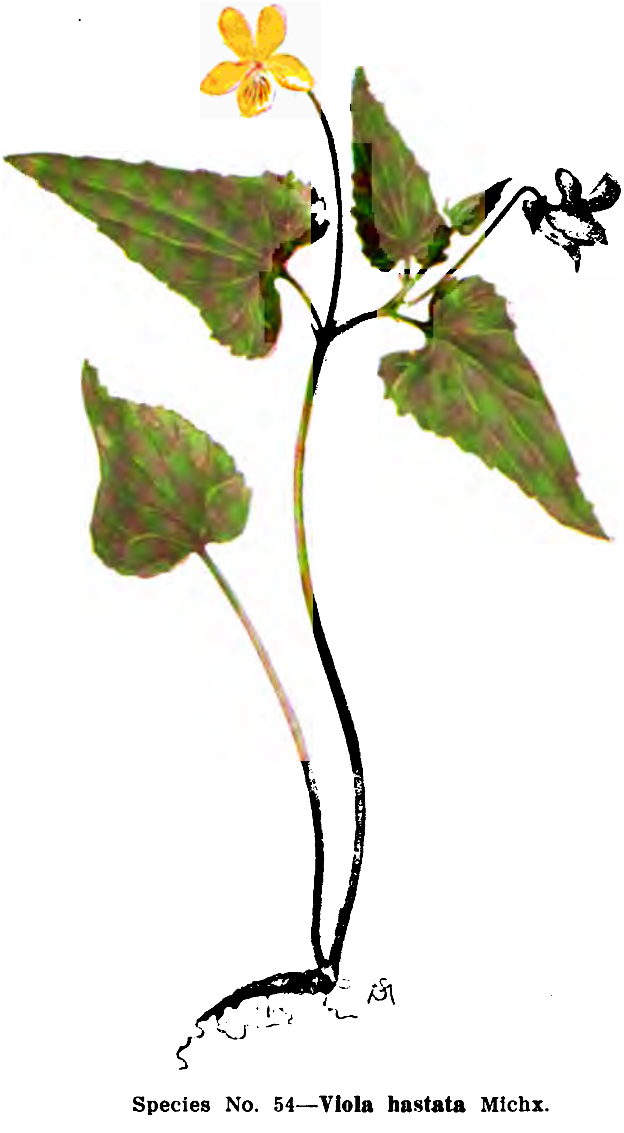
**Species No. 59—Viola pubescens Ait.**



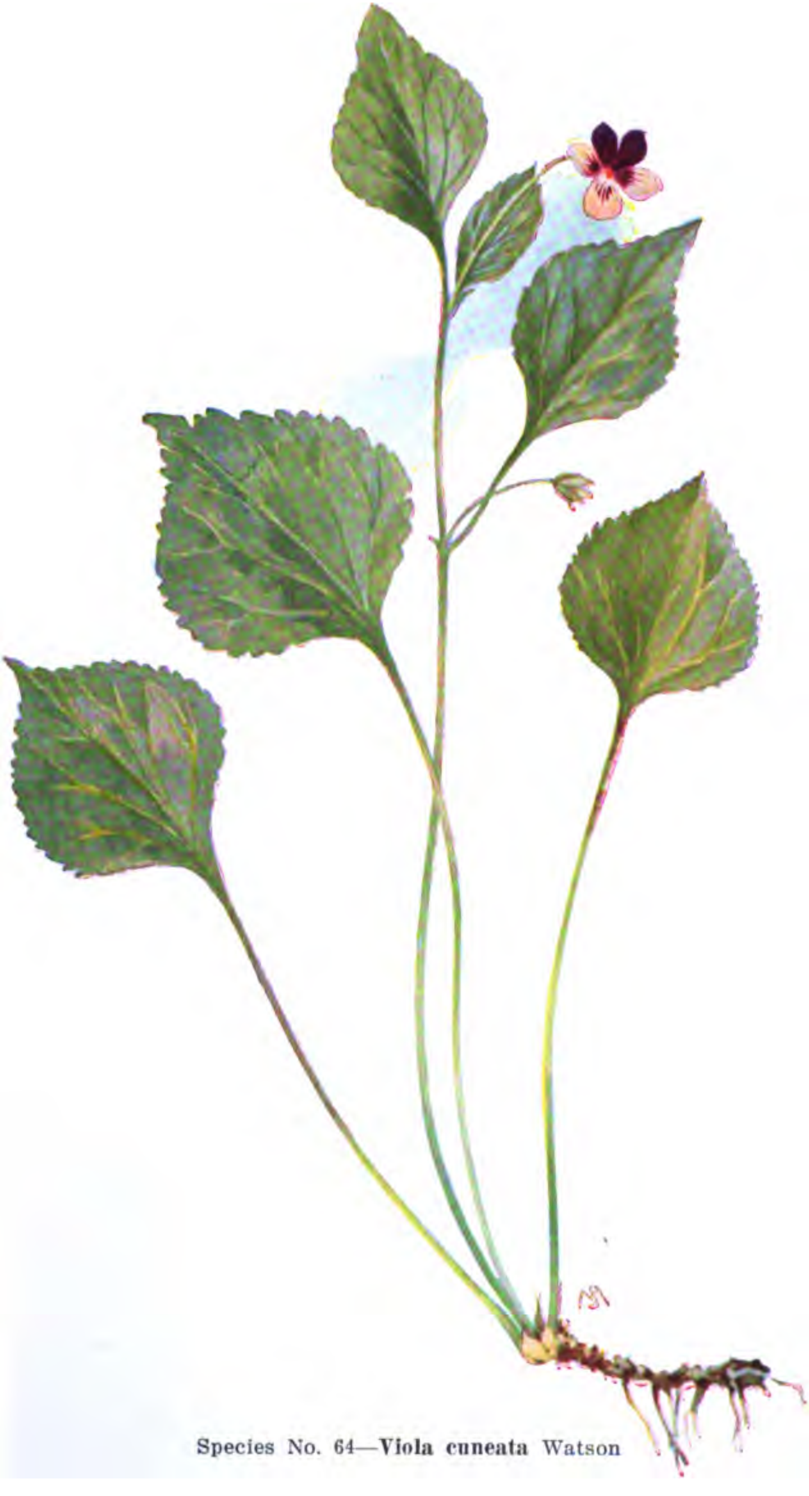
Species No. 49—**Viola chrysantha** Hooker



Species No. 52a—**Viola Hallii** Gray



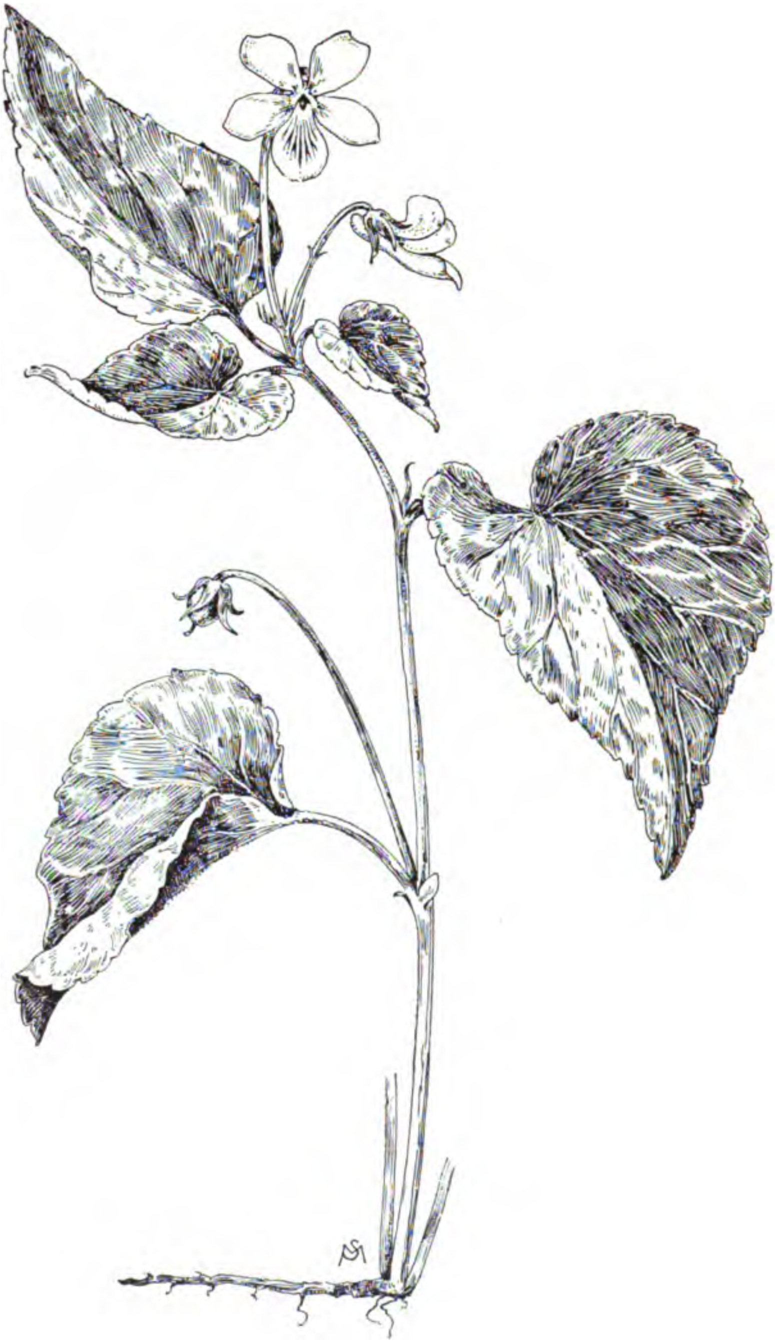
Species No. 54—**Viola hastata** Michx.



Species No. 64—**Viola cuneata** Watson

Schweintz at first called his plant *scabriuscula* from "the dispersed hairs on the nerves" and under *V. pubescens* a variety *scabriuscula,* is given in Torrey and Gray's Flora, 1838, citing "*V. scabriuscula* Schwein. MS." In 1886, Gray well said it "should have been named *glabriuscula* for it really is not scabrous." In habitat *V. pubescens* affects dry, rich woodlands, *V. eriocarpa,* low open woods and rich meadow bottoms.

Our illustration of *V. eriocarpa* is from a herbarium specimen collected near Muskogee, Okla., March 31, 1908; that of *V. pubescens* is a copy of Reichenbach's Ic. Pl. Crit. 1 : 45, t. 53, fig. 111, 1823. Specimens of *V. pubescens* may be seen in Nos. 126 and 127 of my Distribution of Violets, 1910, and of *V. eriocarpa* in Nos. 144, 145, 146 and 147.



**Species No. 60—*Viola rugulosa* Greene**

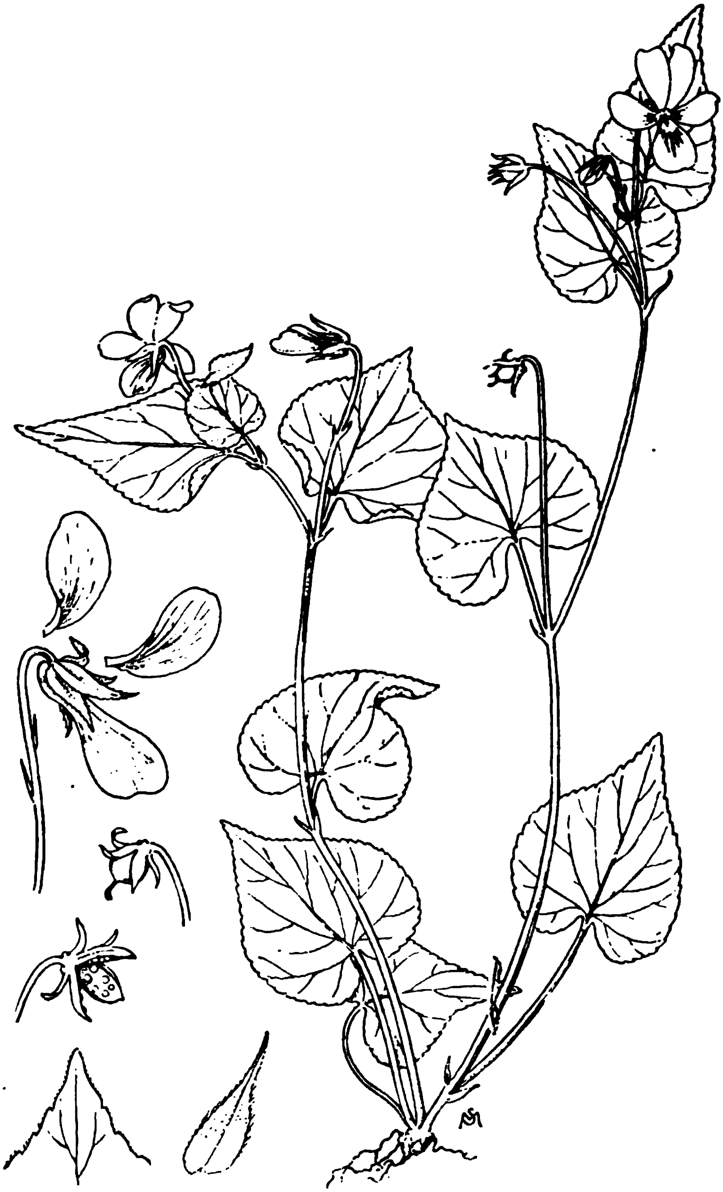
**Viola rugulosa** Greene, Pitt. 5: 26. Sept., 1902. Species No. 60.

The most northern station known is Hazelton, B. C., lat. 55½°, Prof. J. K. Henry, June 11, 1915. It is reported in seven states to the south and east of British Columbia.

1. Montana: Park and Sweet Grass Counties, Eggleston, May 11, and June 25, 1912.
2. Wyoming: Dale County, Greene; Laramie, Coulter.
3. Colorado: Boulder, Fort Collins, Eldora; abundant material from D. M. Andrews, E. Bethel and E. R. Cross.
4. Nebraska: Missouri River bluffs, Dixon County, A. A. Hunter, Coll., June 18, 1900; sent out from U. S. Nat'l Hb. as *V. canadensis.*
5. Minnesota: along Mississippi River at Fort Snelling, 8 miles below Minneapolis.
6. Iowa: Ill. Fl. 2: 559, 1913. Station not reported, probably on the river below Fort Snelling.
7. Washington: First Thought Mountain, Colville Forest, Stevens County, 4,000 ft. alt., July 19, 1916; 13128, Eggleston.

In its characters the species connects *V. pubescens* with *V. canadensis.* It is noteworthy for its vigorous branching stolons, well underground, by means of which the plant spreads rapidly in the wild and in the garden, quite after the manner of Quitch-grass (*Agropyron repens*). This character escaped the attention of Greene who says the rootstock does not seem to differ from that of *V. canadensis.* It attracted my attention when growing plants were examined in the New York Botanical Garden which were received through Mr. Andrews from the Boulder station. This led me to secure live plants from Fort Snelling, through the kindness of Clement, to determine if they were not also stoloniferous. Greene applied the name *rugulosa* only to the Minnesota plant; that of the Rocky Mountain region he named, a page later, *V. Rydbergii.* But the one is hardly distinguishable from the other.

The illustration of *V. rugulosa* is copied from a water-color painted May, 1915, of a specimen ex horto Middlebury, Vt., transplanted from Fort Snelling, Minn., 1911. No. 138 of my Distribution, 1910, represents the Rocky Mountain plant, cultivated from Boulder since 1898 at Bronx Park, N. Y., and also later at Middlebury, Vt.



Species No. 61—**Viola canadensis** L.

**Viola canadensis** L. Sp. Pl. 936. 1753. Species. No. 61.

This, the most widely distributed North American violet, ranges from New Brunswick to Saskatchewan, in the east, south to Alabama, and in the Rocky Mountains south to Arizona and New Mexico. Its habitat is wooded uplands, or in the South, mountain forests. Schweinitz, who lived at Salem, N. C., half way between Raleigh and the Blue Ridge, says it is rarely found there and exclusively in the higher mountains. I have a fruiting specimen from the most western county of South Carolina—House No. 2080, May 5, 1906—and I collected it in flower April 21, 1910, at Mount Tryon, N. C., and near Tuscaloosa, Ala., March 28, 1911, lat. 33°—the most southern known station.

Greene,[1] loth to believe one species could have so wide a range, published four "segregates" that do not appear to be specifically distinct. One he named *V. geminiflora,* the type from Nez Perce County, Idaho. Heller, June 20, 1896, lat. 46½°. I collected it August 21, 1897, on Sulphur Mountain, Banff, Alberta, altitude 6,500 ft., lat. 52°, and have a specimen from Millspaugh, collected June 9, 1913, at Ephraim, Door Co., Wis., lat. 45° 12′, that matches well with the two previous collections. It seems to be only a state of *V. canadensis* not infrequent, where only two flowers appear at the summit of the stem. I regard *V. discurrens, V. neo-mexicana* and *V. muriculata* as also unsatisfactory segregates.

We have selected to illustrate *V. canadensis* a reproduction of Reichenbach's t. 54, fig. 113, Ic. Pl. Crit. 1: 45, 1823. The two lower details represent the tip of a leaf and a sepal enlarged; but the figure of the plant is reduced to one-half its natural size.

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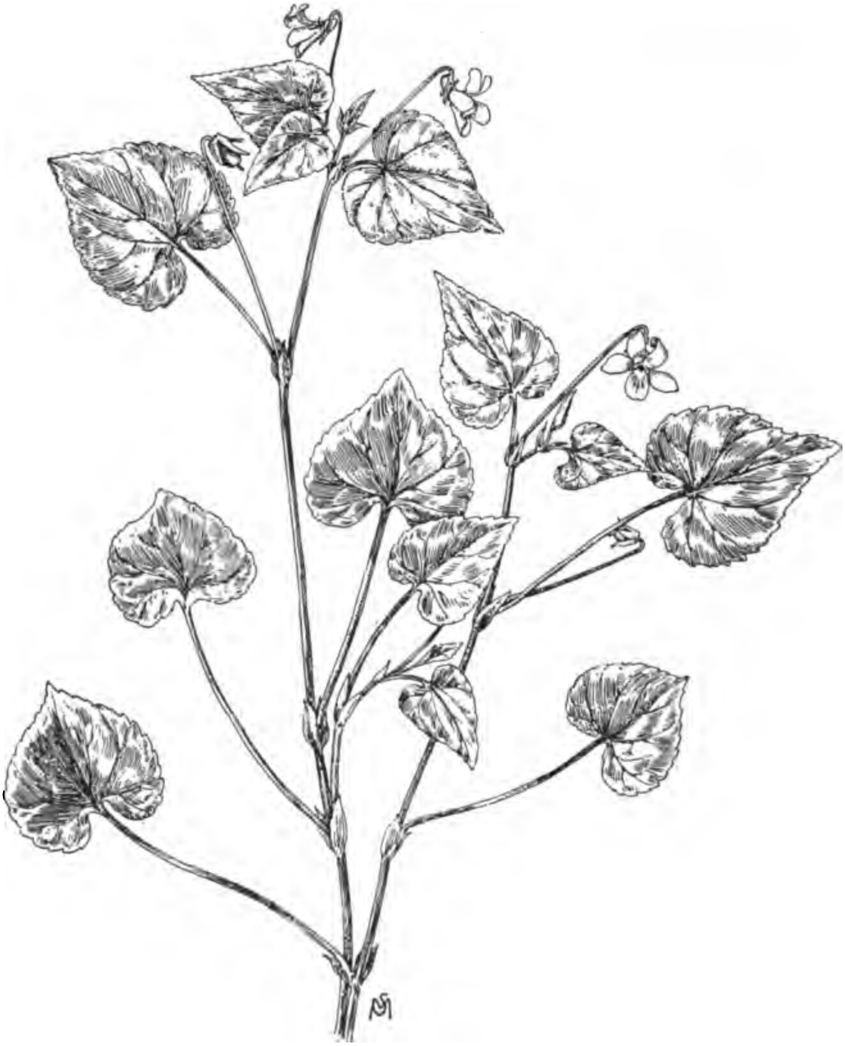
[1] Pitt. 5:24. Sept., 1902.



Species No. 62—**Viola scopulorum** (Gray) Greene

**Viola scopulorum** (Gray) Greene, Pitt. 5: 27. Sept., 1902. Species No. 62.

*V. canadensis* var. *scopulorum* Gray, Bot. Gaz. 11: 291, Nov., 1886.

Gray describes this variety thus: "A diminutive and depressed form of which the most characteristic form was collected in Clear Creek Cañon (Colorado) by Greene." This brief account is fully supplemented by Greene in Pitt. 5: 27.

Through the kindness of Mr. E. Bethel and E. R. Cross, I received living plants from the type station[1] and dried specimens from the vicinity, and after growing the plant for three years was thoroughly convinced of its right to specific recognition. The length of the stem and the size of the capsule, leaf and seed are but half that of *V. canadensis*. The stem branches freely, each branch bearing flowers and abundant fruit as the season advances.

Our line-drawing is from a herbarium specimen ex horto Middlebury, Vt., May 15, 1913, transplanted from Boulder, Colo., July, 1912. E. Bethel, collector and donor.

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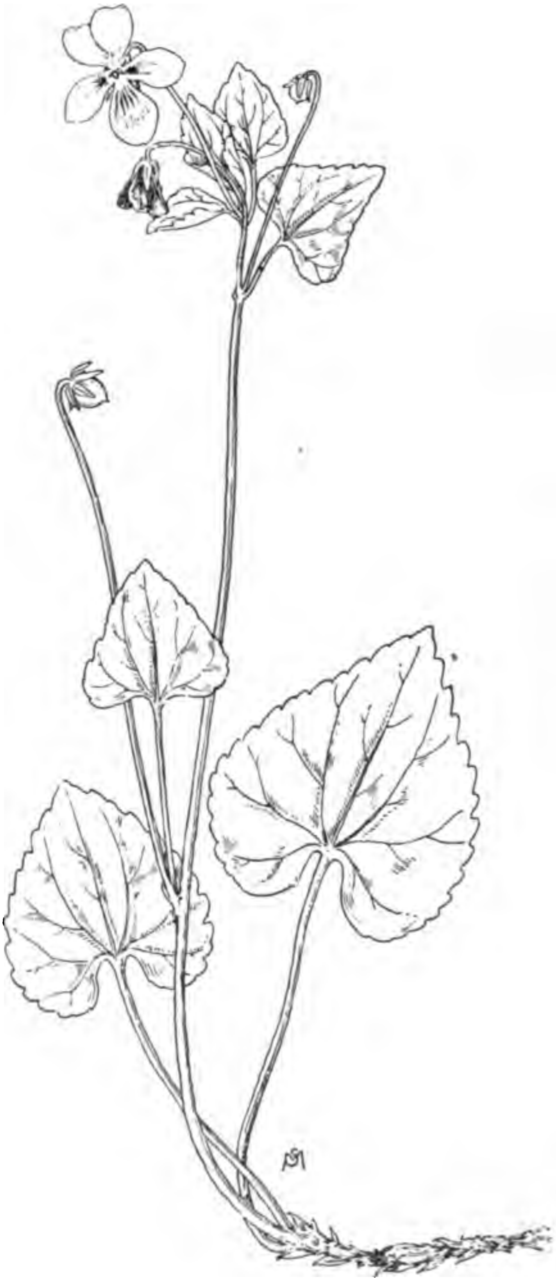
[1] Clear Creek Canyon, Colo.



Species No. 63—**Viola ocellata** Torr. & Gray

**Viola ocellata** Torr. & Gray, No. Am. Fl. 1: 142. July, 1838. Species No. 63.

A woodland species of limited range from Cow Creek Mountains, Ore., to Monterey County, Cal. The upper petals are dark purple; the lateral pale yellow to white with a violet spot at base of each, a character that suggested the specific name "the two-eyed violet"; the lower petal also yellow to white, larger, with several violet striae on the lower half. The rootstocks are often long and stolon-like, several from a bunch of coarse, fibrous roots; from them arise one or more radical leaves and flowering stems with a tuft of scarious stipules at the base.

Beautiful specimens of this species were collected April 15, 1916, in the Santa Cruz Mountains by my daughter, Mrs. Viola Brainerd Baird, of Berkeley, Cal. When put in press, strips of thin paraffin paper were laid over the flowers, to prevent their fading from contact with air or moisture. This method was so successful that even now after six years the color of the flowers, when the paraffin papers are removed, is nearly as good as in Mathews' water-color of this beautiful violet.

The line-drawing is based on a herbarium specimen from Mount Tamalpais, Cal., just north of the Golden Gate, collected June 6, 1899, by Miss Alice Eastwood.

**Viola cuneata** Watson, Proc. Am. Acad. 14: 290. 1879. Species No. 64.

One of the rarest of our western violets first collected in June, 1878, and described by Watson as follows: "glabrous: stem a span long, leafy, ascending from a short rootstock; leaves rhombic-ovate, acute, alternate at base with a slender petiole, crenately toothed above; petals deep purple, more or less bordered or blotched with white, beardless, 4 lines long; spur very short, yellowish; capsule glabrous.—Humboldt County, Cal., on a high, open ridge south of Trinity River; V. Rattan, June, 1878. Allied to *V. ocellata* and *V. Hallii.*" At about the same time this description also appeared in Brewer and Watson's Bot. of Cal., vol. 2, p. 433.

In Gray's final revision of Viola, November, 1886, he says under *V. cuneata* Wats., "mountain woods in the northern part of California and adjacent Oregon. Distinguished from the preceding (*V. ocellata*) by its smoothness and its rhombic-ovate or cuneate leaves, only the radical ones cordate." I have a specimen of this rare species collected by Miss Alice Eastwood in the northwest corner of California, Gasquets, Del Norte County, April 23, 1907; and also specimens from "dry soil in open forest, old Eddy place on Eddy Creek, Shasta Forest, Cal., altitude about 3,500 ft., Eggleston 11,563, August 11, 1915. Upon one of these latter plants is based the color-plate of this species, the flower being drawn like those of *V. ocellata* as described in the Synoptical Flora.

That the species is still rare is shown by the fact that Mrs. Viola Brainerd Baird has recently reported that the mounted specimens from California in the University Herbarium at Berkeley are all from the three northern counties on the coast and from the two adjacent counties of Trinity and Siskiyou.

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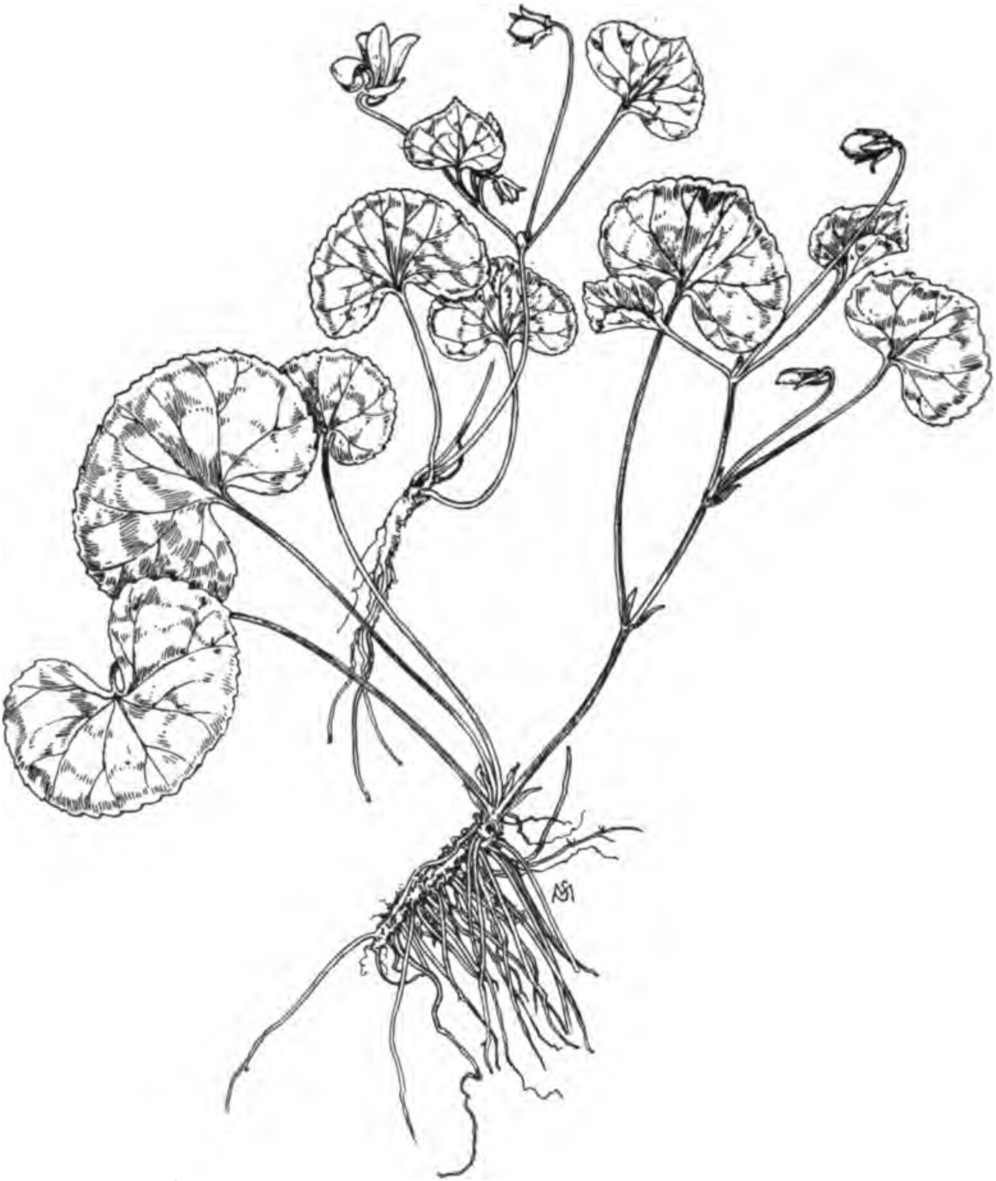
**See color-plate, Species No. 64, opposite page 132.**



Species No. 65—Viola Flettii Piper

**Viola Flettii** Piper, Erythea 6: 69. 1898. Species No. 65.

Only four sheets of this rare and distinct violet are in the National Herbarium, viz.:

1. The type: "Seams of rocks, Olympic Mountains, Wash., July 20, 1897, collected by J. B. Flett, Tacoma, Wash." No. 529,412 Nat'l Hb.

2. Another specimen, "Rocks and crags, summit of Olympic Mountains, July 20, 1897, collected by J. B. Flett." A "cotype." No. 354,059 Nat'l Hb.

3. High cliffs of the Olympic Mountains, near Mount Constance, August, 1898, collected by J. B. Flett. In fruit, No. 529,411 Nat'l Hb.

4. Talus slopes near summit of Mount Angeles, Clallam Co., Wash., July 1, 1908, collected by J. B. Flett. No. 620,483 Nat'l Hb. This mountain is near the south coast of Strait of Juan de Fuca, long. 123½° W.

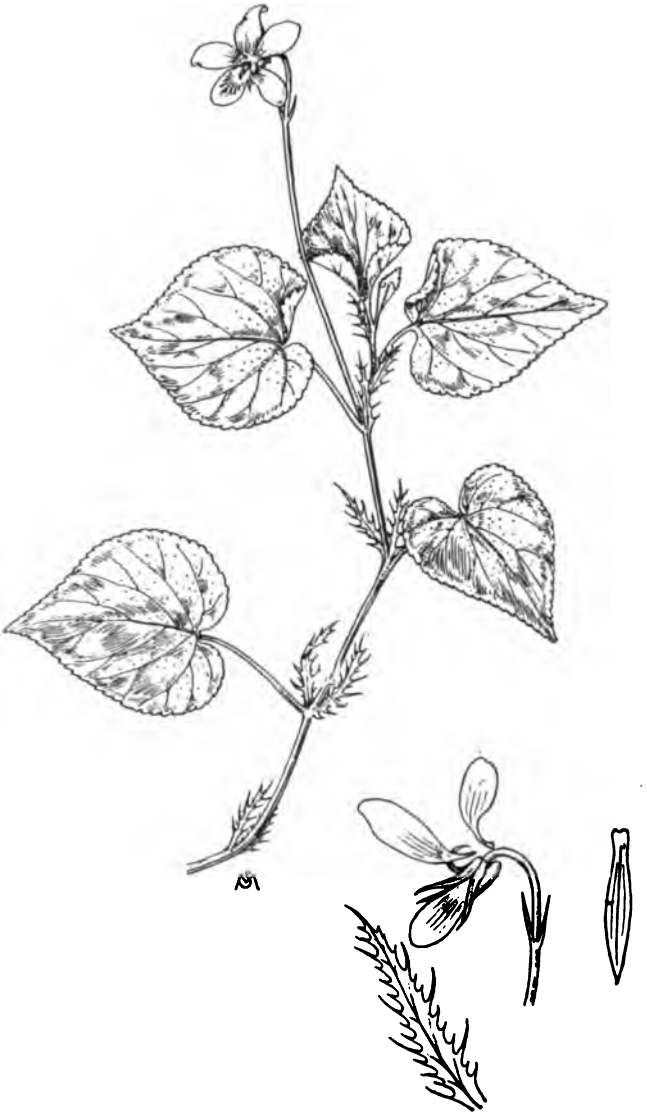
In Piper's Fl. of Wash., p. 394, 1906, a specimen is cited collected by Henderson, No. 1847.

In Piper's and Beattie's Flora of the Northwest Coast, p. 243 (1915) we are told that the species seems most nearly related to *V. cuneata* Watson (1879), i. e., in the structure and color of flower; but in aspect (i. e., foliage) the plant more closely resembles *V. glabella.* Piper describes the petals as "lavender-violet, yellow at base with dark purple veins." Some indication of the color of the petals is to be found in the type specimens and in that from Mount Angeles.

1. The upper petals are dark violet on outer surface or in bud.
2. The lateral petals are striate on the upper surface and bearded.
3. The spur petal is violet with long and numerous dark lines.

The flower is thus much as in *V. cuneata* or *V. ocellata.*

Our line-drawing is based for flowers on specimen 2, a "cotype," July 20, 1897; for fruit on specimen 3, Mount Constance, August, 1898.



Species No. 66—**Viola striata** Ait.

**Viola striata** Ait., Hort. Kew. 3: 290. 1789. Species No. 66.

Its habitat is low, shady ground and along streams; its range, New York to Minnesota, south to Georgia, and southwest Missouri, but apparently rare in the prairies of the Middle West. The specific name was doubtless suggested by the 8-10 purple lines, or striae, by which the spur-petal is adorned for over half its length. It is one of the most variable of our eastern violets.

Apparently the species does not occur spontaneously in New England; the station reported for Connecticut is not recognized in the catalogue of the Connecticut Botanical Society, 1910. But in May, 1906, Mrs. Emily (Hitchcock) Terry sent live plants from her garden in Northampton, Mass., which have since increased with me amazingly in number and in size. One large clump dug up August 23, 1921, had a mass of long, fibrous roots, often branching, and 60 stems bearing cleistogamous flowers and capsules.

*V. ochroleuca* and *V. repens* of Schweinitz[1] are plainly synonyms of *V. striata* Ait. His long account of the habits of these plants as he found them in Salem, N. C., is most instructive. *V. ochroleuca* is tall, large-flowered, in rich soil, borders of ponds and meadows, flowering in April, with large, oblong-lanceolate, "quasi-ciliate" axillary-stipules. *V. repens* is decumbent, spreading and even creeping, with smaller flowers in May, on the rocks of the Saura Mountains in considerable patches, the axillary-stipules ovate, strongly fringed. One might suspect that *V. repens* was a local form whose prostrate stems rooted and became stolons, as in the kindred species *V. Walteri.*

On my southern trips in April, 1908, 1909 and 1910, I collected *V. striata* at several stations in the higher mountains of western North Carolina. One of these is No. 164 of my Distribution of Violets, 1910. In No. 165 is to be seen the autumnal state of the species as grown in Middlebury, Vt., from the Northampton stock.

The line-drawing is a reproduction of Reichenbach's "Plantae Criticae" 1: 45, t. 54, fig. 112, 1823; his specimen is said to be from Philadelphia.

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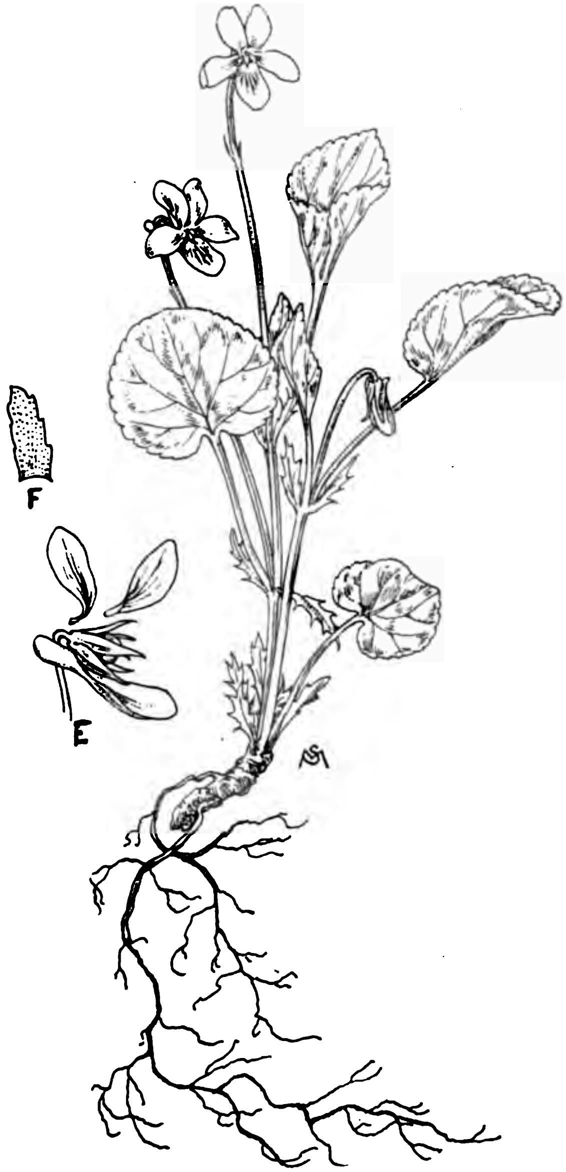
[1] Am. Jour. Sci. V: 69-71. April, 1822.



Species No. 67—**Viola conspersa** Reichenb.

**Viola conspersa** Reichenb., Plantae Criticae 1: 44, pl. 52, fig. 108. 1823. Species No. 67.

In addition to the color-plate we give a line-drawing of Reichenbach's fig. 108. In his description he states that the leaves are marked with black dots and lines on the lower surface, as is represented by the detail marked F in the line-drawing. This appearance doubtless suggested the specific name *conspersa,* i. e., besprinkled. However, this dotted or minutely speckled herbage is not a proper character, but the effect of a fermentation induced by enzymes in specimens poorly dried or later exposed to moisture and heat.[1] It has been observed in many species of *Viola,* and has suggested other specific names. Schweinitz, unaware of Schrank's *V. labradorica,* named specimens from Labrador *V. punctata* because they were covered with raised glandular dots.[2] *V. maculata* Cavan, from the Falkland Islands, is another similar name.

The earliest recognition of the plant is supposed to be the "*V. asarifolia*" of Muhlenberg's Catalogue; but this is a "mere name" and is antedated by *V. asarifolia* Pursh. Torrey[3] published it in 1824 as *V. Muhlenbergii.* Later, Gray[4] disposed of it as "var. *Muhlenbergii*" of *V. canina* L., an old world species. There the matter rested until in Britton's Ill. Fl., 1st ed., 1897, it was incorrectly identified with *V. labradorica* Schrank. In March, 1911, the present writer called attention to *V. conspersa* Reichenb. as the oldest available name.[5]

The known range of the species is from eastern Quebec to Minnesota and south to the mountains of northern Georgia. It is closely allied to *V. adunca* (No. 71) and to *V. labradorica,* which is found as far north as Greenland, and takes the place of *V. conspersa* in Newfoundland. Farther south *V. labradorica* occurs only in the high mountains of New England. See line-drawing No. 68, of a specimen of this from Mount Albert, Gaspe District, Que.

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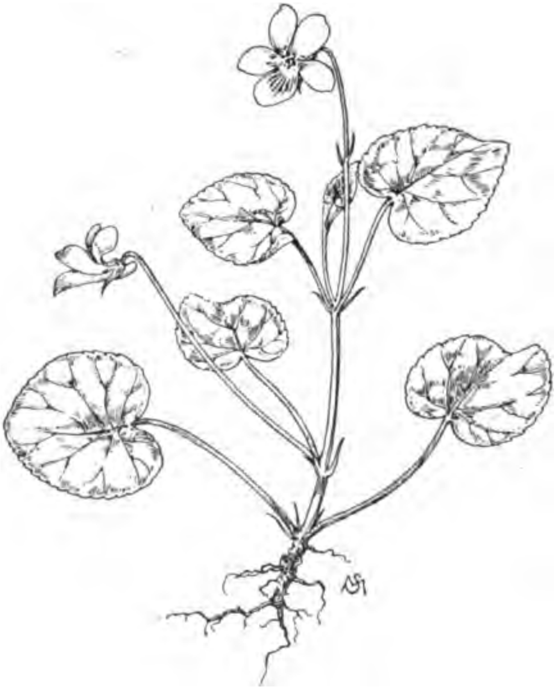
[1] See footnote, Rhod. 15: 110. June, 1913.
[2] foliis. . . . punctis glandulosis tectis.
[3] Fl. U. S. 1: 256.
[4] Bot. Gaz. 11: 292.
[5] Bull. Torr. Cl. 38: 195.

See also color-plate, Species No. 67, opposite page 160.



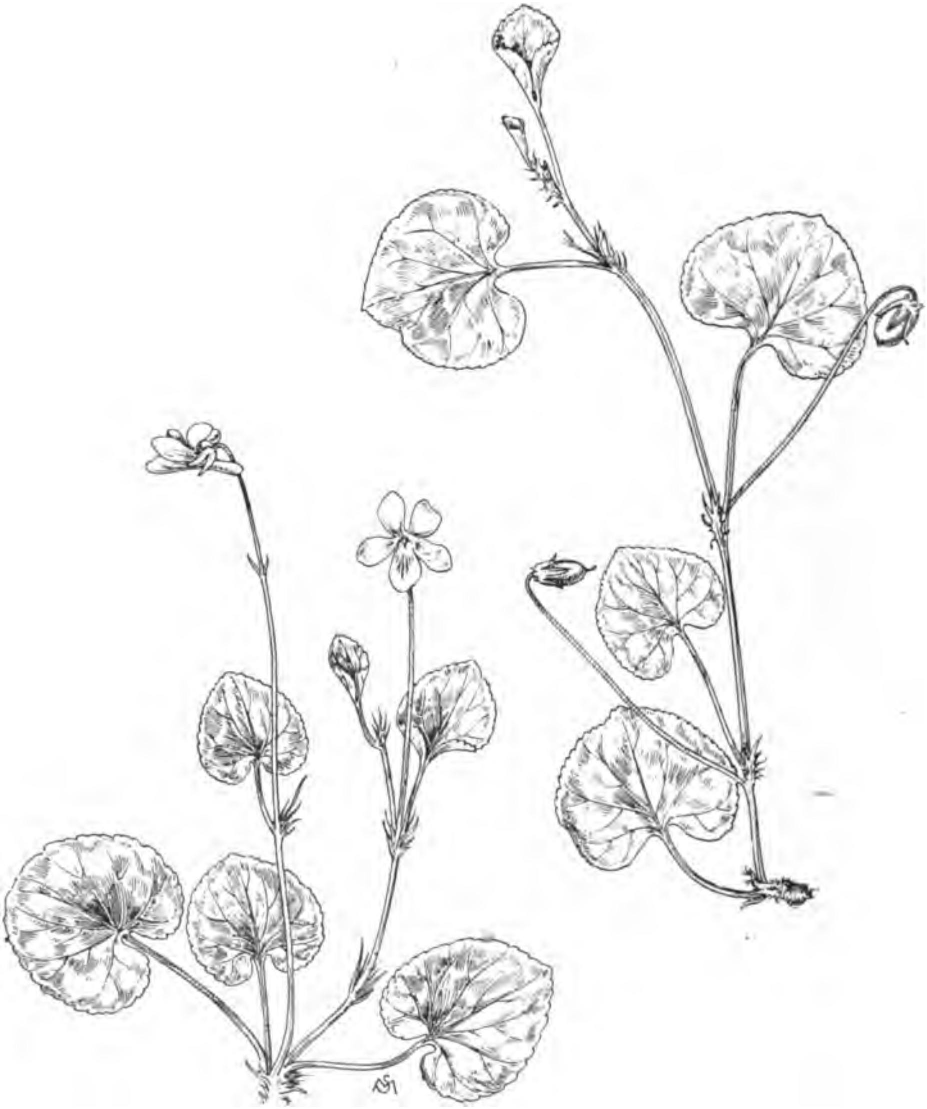
Species No. 68—**Viola labradorica** Schrank.

**Viola labradorica** Schrank, Denksch. Bot. Gesell. Regensb. 2: 12. 1818. Species No. 68.
*V. punctata* Schwein., Am. Journ. Sci. 5: 67-68. 1822.
*V. Muhlenbergiana* Hook., Fl. Bor. Am. 1: 178. 1830.

This small species ranges from Greenland south along the Labrador coast to Newfoundland, where it takes the place of *V. conspersa* Reichenb., thence to the mountains of the Gaspe Peninsula, altitude 2,300-3,500 feet, and of Maine, New Hampshire and New York. In habitat it reminds one of *V. glabella* of the far west, that ranges from arctic Alaska to middle California, near the cold waters of the coast or in the highlands of the Sierra Nevada at an altitude of 3,500 to 7,500 feet.

Schweinitz, when living at Salem, N. C., received specimens of Schrank's plant from his "revered friend, Rt. Rev. C. G. Hueffel," then a Moravian missionary in Labrador. In ignorance of Schrank's name he published the plant as *V. punctata* because of its minutely speckled herbage.

Our line-drawing is based on a herbarium specimen from Mount Albert, Gaspe District, Que., Collins and Fernald, coll., August 11, 1905.

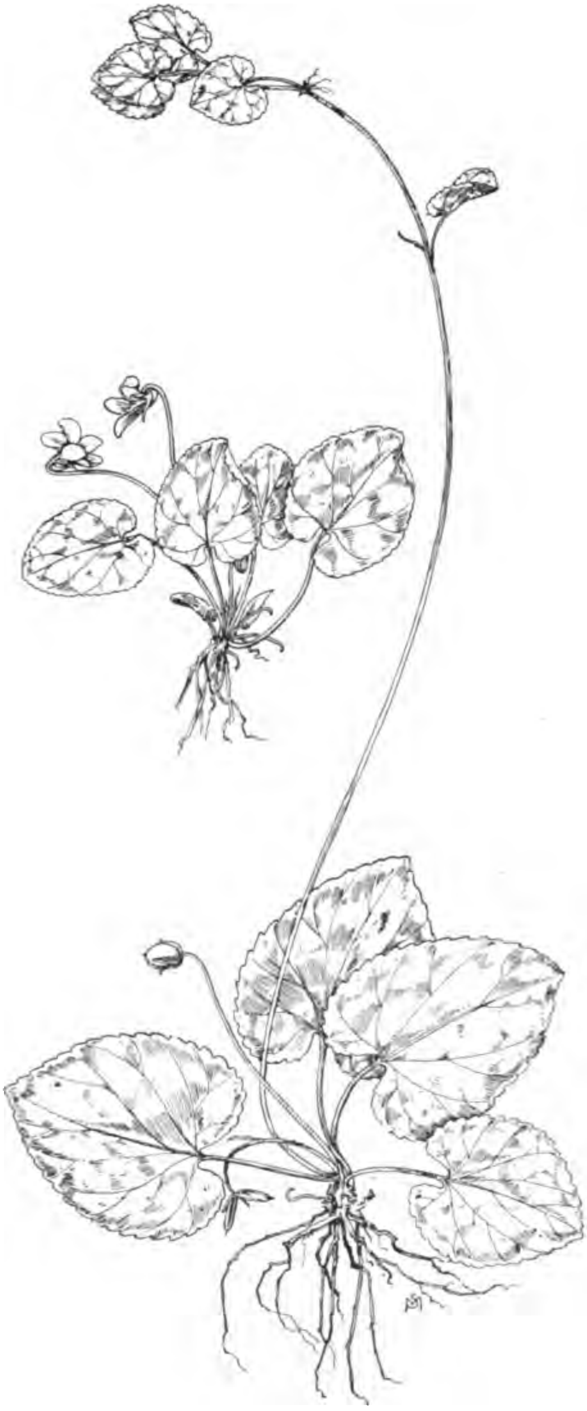


**Species No. 69—Viola Walteri House**

**Viola Walteri** House, Torreya 6: 172. Aug., 1906. Species No. 69.
*V. canina* Walt., Fl. Car. 219, 1788; not L., 1753.
*V. striata* Ell., 1817; not *V. striata* Ait., 1789.
*V. debilis* Schwein., 1822; not *V. debilis* Michx., 1803.
*V. Muhlenbergii* var. *multicaulis* T. & G. Fl. 1: 140, 1838.
*V. multicaulis* (T. & G.) Britton, Mem. Torr. Cl. 5: 227, 1894; not Jordan, 1852.

This species is found in dry woodlands from Kentucky to South Carolina, south to Gainesville, Fla., and west to Texas. It flowers in early spring from a tuft of radical leaves; later it sends out an ascending but soon prostrate stem, bearing cleistogamous flowers through the season and at length rooting at the tip. In this method of reproduction it resembles *V. odorata,* classed as a stemless violet with surface runners that bear leaves and cleistogamous flowers and later form new plants. We have in *V. Walteri* a fine illustration of the metamorphism of stems into stolons.

The line-drawing shows a flowering stem, collected at Mansfield, La., March 28, 1910, and a fruiting stem ex horto Middlebury, Vt., August 29, 1911, transplanted from the Louisiana station.



Species No. 70—**Viola reptans** Robinson

**Viola reptans** Robinson, Proc. Am. Acad. 27: 165. 1892. Species No. 70.

*V. Pringlei* Rose & House, Cont. U. S. Nat. Mus. 29: 444. 1905.

The description is based on material collected in November, 1890, among the hills of Patzcuäro, Michoacan, Mex. (C. G. Pringle's No. 3591). For petaliferous flowers it should be supplemented by collections made in spring or summer.

Through the courtesy of Mr. W. R. Maxon, Associate Curator, the following specimens have been secured for study from the National Herbarium.

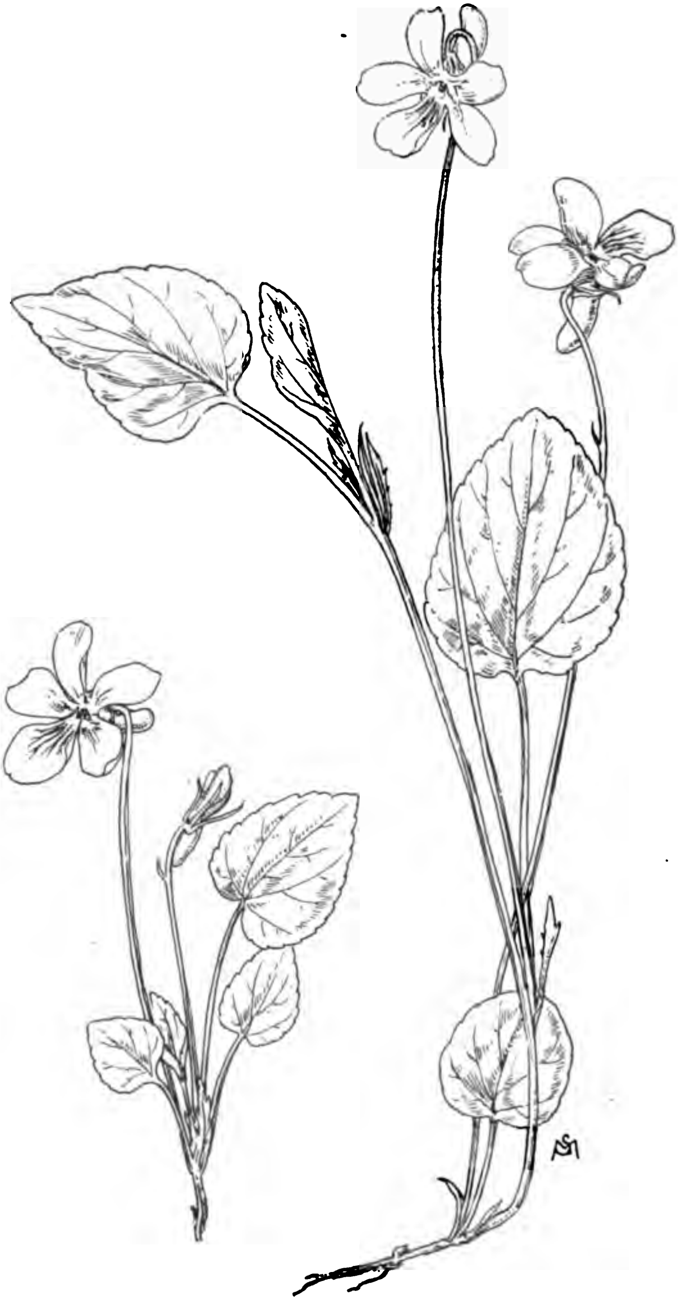
| *Town* | *State* | *Latitude* | *Collector* | *Date collected* | *Number in National Herbarium* |
|---|---|---|---|---|---|
| **Cuernavaca** | **Morélos** | **18° 55′** | **Rose and Hough** | **5/27-30/99** | **346,787** |
| **Pāchucha** | **Hidalgo** | **20° 10′** | **Rose and Hough** | **6/1/99** | **346,440** |
| **Säläzär** | **Mexico** | **19° 30′** | **Rose and Painter** | **9/4/03** | **451,657** |
| **Patzcuäro** | **Michoacan** | **19° 30′** | **C. G. Pringle** | **7/3; 10/14/92** | **7,491** |
| **Cañon San Luis Mountains** | **Southwest corner of New Mexico** | **31° 30′** | **Dr. Edgar A. Mearns** | **9/11/93** | **233,392** |
| **Animas Valley** | | | | **10/2/93** | **234,593** |
| **Dulce, Apache Reservation** | **New Mexico** | **36° 55′** | **Paul C. Standley** | **8/20/11** | **687,120** |

The petals of *V. reptans* are said by Robinson to be white with blue lines, but in one flower of No. 346 440 Nat'l Hb. the spurred petal has a distinctly violet color. Its form is here seen to be broadly cuneate marked with numerous delicate lines, the lateral petals having only a few branching lines from the bearded base.

The long range of the species northward from Cuernavaca to the north line of New Mexico, a distance of 18° in latitude or 1,243 miles, is noteworthy. But the southern stations are in the cool mountains of the Mexican plateau, which extends along the continental divide to Dulce, the station for No. 687 120 Nat'l Hb., where the altitude is 7,256 feet.

The line-drawing is based on Pringle's specimen No. 7491 Nat'l Hb., from the type station, collected the same year (1892) that the species was published by Robinson.

Excellent specimens are found in the Pringle Herbarium, University of Vermont.



Species No. 71—**Viola adunca** J. E. Smith

**Viola adunca** J. E. Smith, Rees's Cyclopedia 37, Viola No. 63. 1817.
Species No. 71.

The type is said to be a plant brought by Mr. Menzies from the west coast of North America. The species is a northern one, growing in sandy or sterile soil and extending across the continent from eastern Quebec and Maine west to British Columbia—reaching southward in the Rocky Mountains to northern New Mexico, and along the Pacific coast to central California.

The plant is well marked by the downy pubescence of stem and leaf, the long spur of the flower, the abundance of cleistogamous fruit in late summer and by its dark brown seeds. But a plant of such wide range naturally assumes various aspects which tempt to the making of new names. The species, however, was disposed of by Gray[1] as simply a variety of *V. canina* L., coordinate with var. *Muhlenbergii* (now *V. conspersa*).

Soon began a movement in the opposite direction. In 1897[2] in Britton's Ill. Fl. the plant was described at the suggestion of Dr. Rydberg, as *V. arenaria* DC.[3]

The radical difference between these two species was set forth by the present writer in Rhodora 15: 106-111, pl. 104, June, 1913. Several other misapprehensions regarding *V. adunca* were pointed out. For example, the hooked spur that suggested the specific name is a most variable character, often tapering to a point instead of forming a hook, and often forming one or more protuberances on the upper side. Several pseudo-species have been founded on these trivial malformations, such as *V. oxyceras* (sharp-horned), *V. odontophora* (toothed), *V. unguiculata* (clawed), *V. drepanophora* (sickle-bearing), *V. mamillata* (nippled), *V. uncinulata* (finely barbed). Watson would distinguish all the forms with straight, blunt spurs as var. *longipes*. But both straight and hooked spurs are at times to be seen on the same plant. Greene has based numerous species on the contour of the leaves and on the character of the pubescence. A complete list of synonyms would contain 50 or more names.

The color-plate is of a specimen from a sterile pasture in South Bristol, Vt., May 24, 1914.

The line-drawing is of two plants from Lake Shawnigan, Vancouver Island, B. C., Prof. J. K. Henry, coll., May 9, 1915. The smaller plant shows a nearly stemless form.

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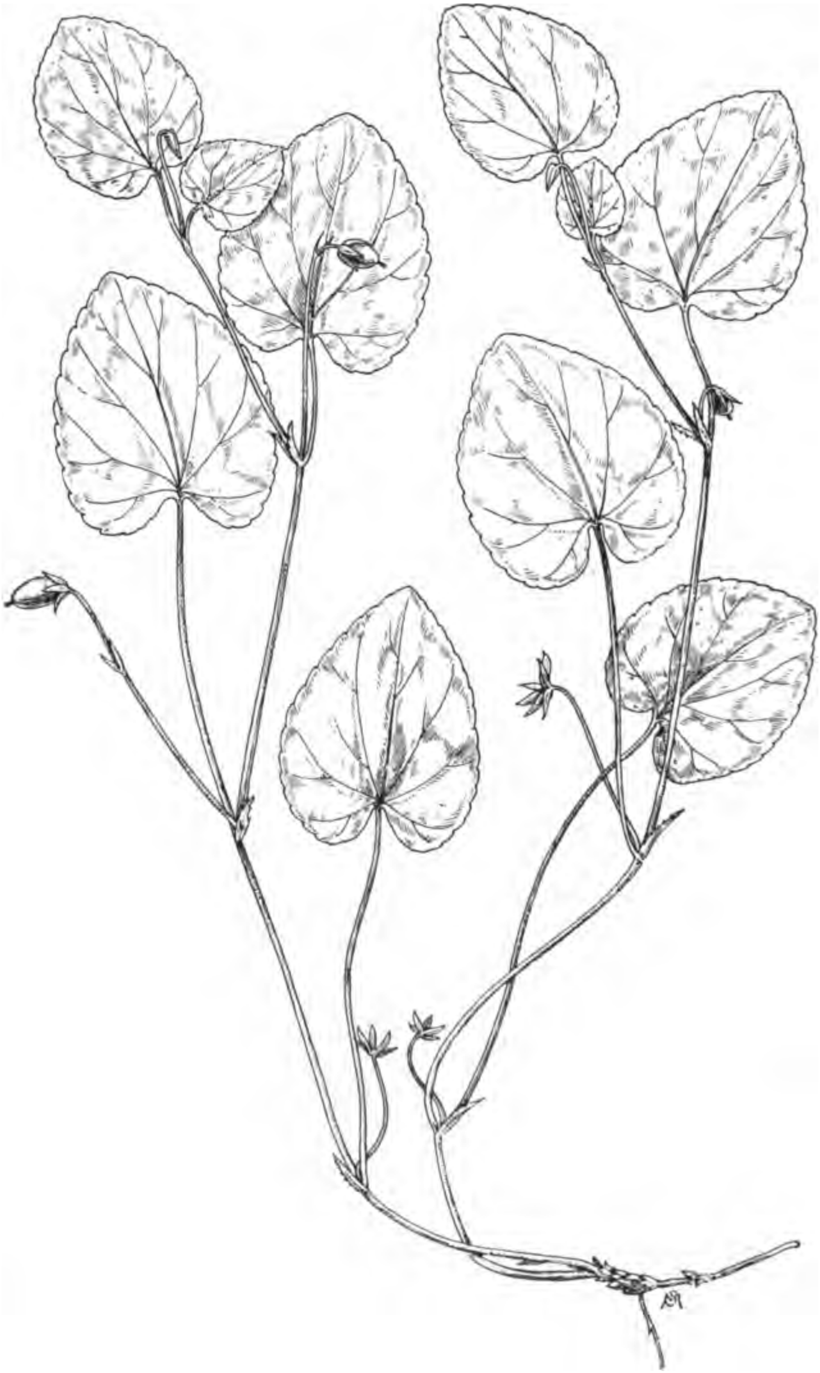
[1] Bot. Gaz. 11: 292. Nov., 1886.
[2] Ill. Fl., 1st ed., 2: 454. 1897.
[3] Fl. Franc. 4: 806. 1815.
**See also color-plate, Species No. 71, opposite page 160.**



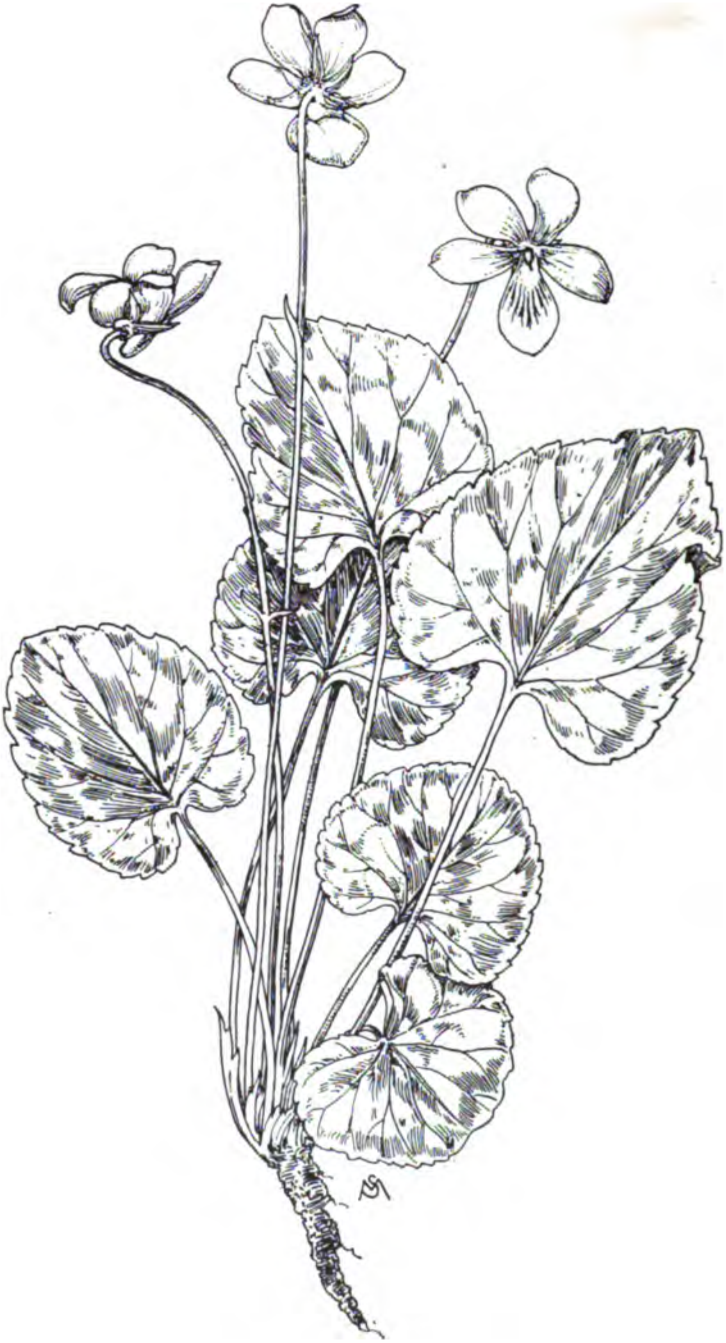
**Species No. 72—Viola Howellii Gray**

**Viola Howellii** Gray, Proc. Am. Acad. 22: 308. 1887. Species No. 72.

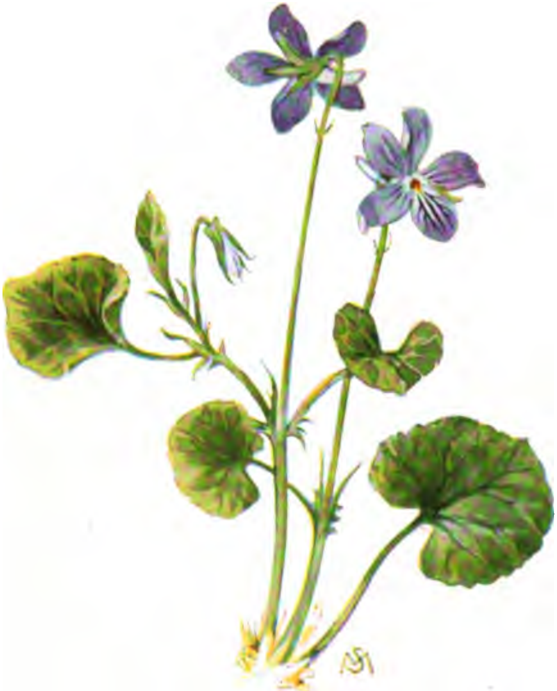
The history of this rare species of the Pacific coast is interesting. It was first collected by Thomas Howell near Portland, Ore., in coniferous woods. In the Bot. Gaz. for November, 1886, Gray "somewhat doubtfully" referred it to *V. mirabilis* L. with this brief description: "Stipules entire or nearly so, linear; flowers on scapes from the rootstock and few on 1- to 3-leaved ascending stems pretty large." A year later, however, he published *V. Howellii* as given above. In his "Flora of Northwestern America," p. 72, March, 1897, Howell gives a fuller and better description of the Portland type. In the Synop. Flora, October, 1905, two additional stations are cited: Klickitat County, Wash., Suksdorf, May, 1885, and Salem, Ore., Henderson. In Piper and Beattie's "Flora of the Northwest Coast," p. 243, 1915, the range is said to be "prairies and open woods, Vancouver Island to Oregon."

I find some additional data as to range in my own herbarium. (1) Shawnigan Lake, Vancouver Island, B. C., J. K. Henry, May 8, 1912; (2) woods, Nanaimo, Vancouver Island, J. K. Henry, July 2, 1912 and April 8, 1915; (3) a live plant was sent me September 11, 1917, from near Salem, Ore., by Geo. M. Darrow, and was grown for several years, bearing flowers and fruit in abundance, apparently not much modified by its new environment; (4) along Mosquito Creek, altitude 600 meters, Okanogan County, Wash., Eggleston, No. 13030, July 14, 1916, west of Colville Forest and about 20 miles south of British Columbia line.

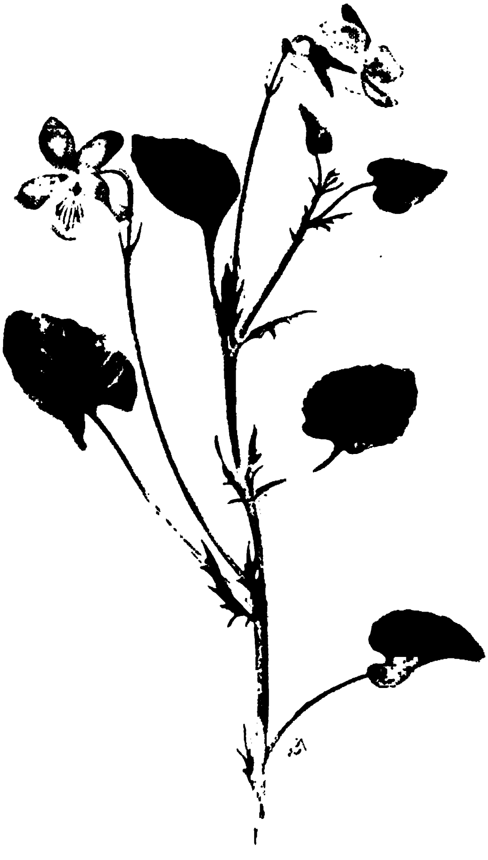
Our illustration is based on a tracing of one of Suksdorf's specimens from western Klickitat County, Wash., above cited—No. 91,325 of the Field Museum, Chicago, reduced to two-thirds the natural size.



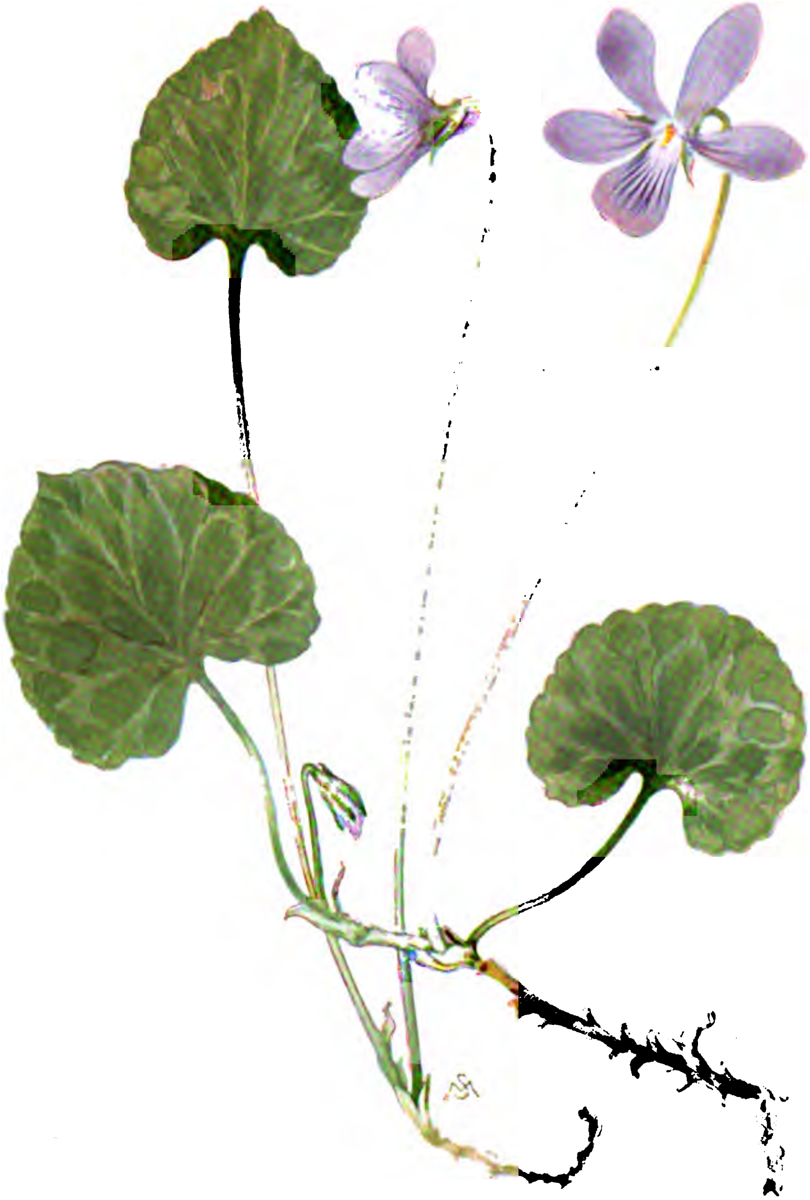
**Species No. 73—Viola Langsdorfii Fischer**



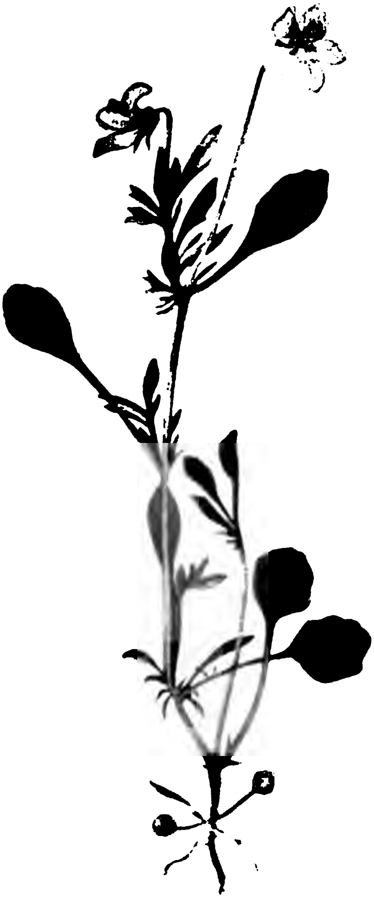
Species No. 67a—**Viola conspersa** Reichenb.



Species No. 71a—**Viola adunca** J. E. Smith



Species No. 73—**Viola Langsdorfii** Fischer



Species No. 75—**Viola Rafinesquii** Greene

**Viola Langsdorfii** Fischer, D. C. Prodr. 1: 296. 1824. Species No. 73.

The type, from Aleutian Islands, Alaska, was collected by Chamisso, a distinguished son of a French nobleman, of whom we find an interesting account in the Encyclopedia Britannica. In 1815 he was appointed botanist on the Russian ship Rurik, and sent on a three years' voyage of exploration around the world. The type of the violet was published in Moscow by Regel as a variety of *V. mirabilis* L. From one of his figures we copy a line-drawing showing a stemless form of the species.

In 1893 the writer received from a former pupil, Rev. Dr. John Chapman, now a missionary of the Protestant Episcopal Church in Alaska, specimens of *V. Langsdorfii* from the type station on Unalaska Island. The plants are small without apparent stems, but the flowers are large, with broad petals, the three lower bearded at the base.

Prof. J. K. Henry of Vancouver City, B. C., collected (May 9, 1895) beautiful specimens of this violet on the moist margin of Lake Shawnigan, Vancouver Island. Our color-plate is based on two stems of this collection, in which the brown rootstocks are seen to be distinct from the short, green stem bearing a bud at the tip. In other plants this stem is one to one and one-half inches in length

In the Synoptical Flora a station is reported from Oregon, and in Howell's Flora of Northwest America, 1897, from Crescent City, Del Norte Co., Cal.; but it was left for Mrs. Viola Brainerd Baird to find a still more southerly station on the coast of California. On July 20, 1915, we visited Fort Bragg and Noyo in Mendocino County to identify a plant collected by Bolander in swamps at Noyo, 1867, and marked in pencil by Gray as "large *V. canina.*" We found the plants in abundance called *V. canina* L. var. *adunca* Gray in the Synoptical Flora, now passing as *V. adunca* Smith[1]; and while the specimens were being carefully put in press by the writer, Mrs. Baird had the good fortune to discover plants of *V. Langsdorfii;* and Noyo thus became its most southern station on the Pacific coast.

This species presents an interesting transition between the stemmed and the stemless violets. In Torrey and Gray's Flora (1838) the species is said to be caulescent; in the Synoptical Flora it is placed in a section headed "strictly acaulescent."

The line-drawing is a copy of Regel's t. 6, fig. 26, Bull. Soc. Nat. Moscow XXXIV, pt. 2, 472.

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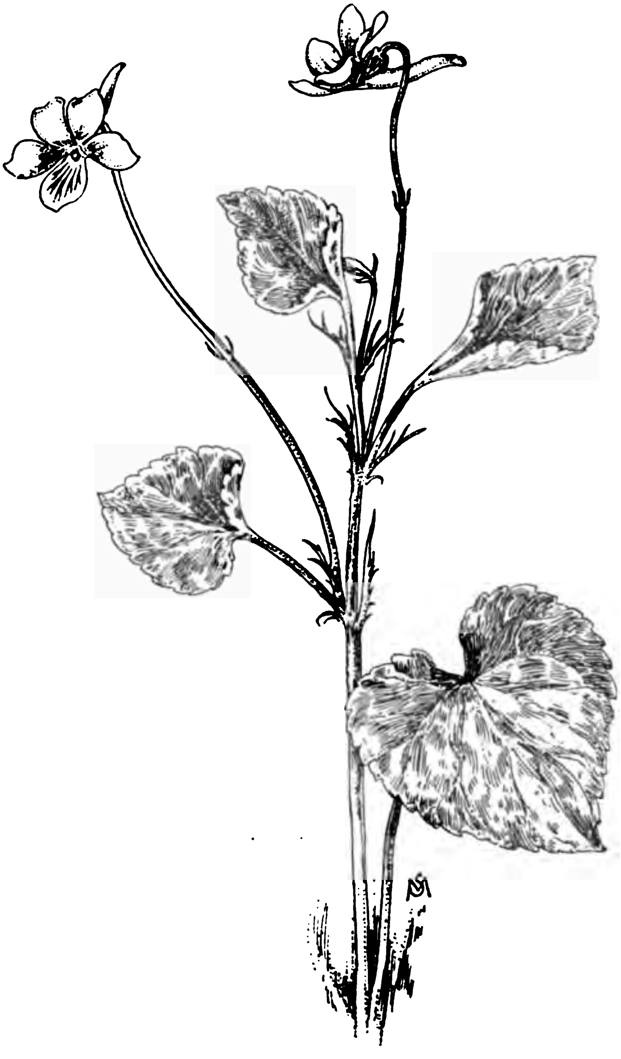
[1] Species No. 71.
See color-plate, Species No. 73, opposite page 160.



Species No. 74—**Viola rostrata Pursh**

**Viola rostrata** Pursh, Fl. Am. Sept. 1: 174. 1814. Species No. 74.

"On shady rocks near Easton, Pa." This is the only eastern violet that has no synonym, as its extremely long spur distinguishes it conspicuously from all other species. The spur, however, is variable. Normally straight and blunt, it is at times strongly hooked or attenuated to a fine point.

The species is otherwise closely allied to *V. conspersa* and indeed hybridizes with it. Some 13 years ago, I received a live plant of this from Plainfield, N. J., from which I raised numerous offspring represented in No. 31 of my Distribution of 1910. And only last May I collected the hybrid in a moist thicket not far from my home in Middlebury, Vt.

The species is found in leaf-mould, usually on shady hillsides, from western Quebec to Michigan and southward in the Appalachian Mountains to Georgia.

The line-drawing is copied from a beautiful water-color painted by Mathews, May, 1915, from a living specimen.

**Viola Rafinesquii** Greene, Pitt. 4: 9. Jan., 1899. Species No. 75.
*V. bicolor* Pursh, 1814, *not* Gilibert, 1781.
*V. tenella* Raf., 1819, *not* Poiret, 1810.
*V. tricolor* var. *arvensis* Gray in part, *not* D. C.

This species, the only American representative of the old world pansy group, is an annual, as is shown in our color-plate by the root and the pair of small seed-leaves at the base of the stem. Gray was reluctant to admit this violet as an indigenous species. In his final revision, October, 1886, he says, "I had always taken this field form of the pansy for a mere escape from cultivation, but in occurs in rather numerous localities from Canada to Texas; several botanists familiar with it insist that it is indigenous."

In his letter to Hooker, in 1841, we find the following statement regarding Constantine Rafinesque-Schmaltz, for whom this violet was named. "A Sicilian by birth, first arrived in the United States in 1802, for three years; returned in 1815, and explored the Alleghanies and Southern States. An eccentric but certainly gifted personage, connected with the natural history of this country for the last 35 years." Rafinesque died in 1840.

The range of *V. Rafinesquii* is from New York to Michigan, thence southwest to Dallas, Tex., and from New York south to the mountains of the western Carolinas and northern Georgia. But an isolated colony is reported from the foothills of Boulder, Colo.

Our color-plate was made from a painting by Mathews, which was based on a specimen from Baldwin, Kan., collected by Rufus Crane, April 19, 1913. The plant is also found in my Distribution of Violets, 1910, No. 128, from near Muskogee, Okla., April 4, 1910.

*V. arvensis* Murray is an old world species resembling *V. Rafinesquii* and is naturalized and even a troublesome weed in the South. It has petals usually shorter than the sepals; the petals of *V. Rafinesquii* are twice the length of the sepals.

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See color-plate opposite page 160.

## III. VIOLET HYBRIDS OF NORTH AMERICA

I am asked to prepare a statement for the Violet Bulletin, emphasizing the important function of hybridism in furnishing new forms for natural selection to work upon. This has led me to look over my mounted specimens of violet hybrids from the wild and from garden cultures. The large number of sheets that I find is surprising even to myself—984—about as many as my herbarium sheets of the species. The total number of distinct hybrids is 89, of distinct species 75.

I may here state that in my first paper on hybrids (Rhodora 6: 213-223, pl. 58, Nov., 1904) the eight there described were from familiar species and were correctly determined as to parentage, and the parents designated by valid names. In March, 1906, 16 months later, I described 25 other hybrids occurring along the southeastern New England coast and southward. Some 11 of these hybrids were between a pair of species, at least one of which was currently passing under an invalid name. On account of this unsettled condition of specific names I deemed it best for a while not to publish the supposed parental names of a hybrid, and, accordingly, for a period of six years I devoted my study of *Viola* largely to the work of clearing up this nomenclatorial confusion. I visited the herbaria and libraries at Cambridge, Mass., Bronx Park, N. Y., Washington, D. C., Charleston, S. C. and St. Louis, Mo. I collected abundant herbarium specimens in the southern and southwestern States, shipping home living plants of both hybrids and species for garden cultures on as large a scale as practicable.

I have given an account of my work on the 75 species of North American violets in the preceding pages; and in the six which follow appears a list of the 89 hybrids which I have in my herbarium. The facts concerning their distribution, the number of sheets of each hybrid in my herbarium and, in cases where the hybrid has been discussed, the place of publication are also cited.

A detailed discussion of violet hybrids will appear in a future bulletin of this Station.

| NAME | STATIONS | SHEETS IN HB. E. B. | WHERE PUBLISHED |
|---|---|---|---|
| *V. adunca* × *conspersa.* | Proctor, Vt.<br>Little Notch, Bristol, Vt.<br>Ex horto 1911, 1912.<br>Ottawa, Ont., 1904. | 5 | Ined. |
| *V. affinis* × *Brittoniana.* | Bradley Ave., Staten Is., N. Y.<br>Ex horto 1911. | 2 | Ined. |
| × *cucullata.* | Middlebury, Vt.<br>Eastern Conn.<br>Ex horto from W. J. Vreeland | 4 | Rhod. 8: 49.<br>Distrib. 1910, No. 7. |
| × *emarginata.* | Englewood, N. J.<br>Ex horto 1908, 1910 | 2 | Ined. |
| × *fimbriatula.* | Staten Island, N. Y.<br>New Jersey.<br>Pennsylvania.<br>Ex horto. | 15 | |
| × *hirsutula.* | Glen Alpine, D. C., 1908.<br>Kenilworth, N. J., 1910. | 7 | Rhod. 8: 56.<br>Rhod. 8: 119. |
| × *nephrophylla.* | Providence Is., South Hero, Vt., 1905, 1907, 1910.<br>Ex horto 1906. | 5 | Rhod. 8: 50.<br>Distrib. 1910, Nos. 8 and 9. |
| × *palmata.* | Penfield, N. Y., 1910.<br>Ex horto 1911, 1912. | 1 | |
| × *papilionacea* House. | Woodridge, D. C.<br>Medford and Plainfield, N. J.<br>Tinicum, Pa. | 15 | Rhod. 8: 119. |
| × *sagittata.* | Patuxent, Md.<br>Tinicum, Pa.<br>Staten Is., N. Y.<br>Milltown, N. J. | 17 | Rhodora 8: 55.<br>Amer. Naturalist 44: 235.<br>Distrib. 1910, Nos. 10 and 11. |
| × *septentrionalis.* | Knight's Is., North Hero, Vt.<br>Middlebury, Vt. | 5 | Rhod. 6: 219. |
| × *sororia.* | Diadem Is., North Hero, Vt.<br>Middlebury, Vt.<br>Canandaigua, N. Y.<br>New York Bot. Garden, from Quebec. | 7 | Rhod. 6: 221 |
| × *triloba.* | Plainfield, N. J.<br>Clark Co., Ind. | 7 | Distrib. 1910, Nos. 18, 19 and 20. |

| NAME | STATIONS | SHEETS IN HB. E. B. | WHERE PUBLISHED |
|---|---|---|---|
| *V. Brittoniana* × *cucullata.*<br>*"septemloba."* | Woodmere, Long Is., N. Y.<br>Fairfield and Stratford, Conn.<br>Milton and Springdale, N. J. | 34 | House, Bull. Torr. Cl. 32: 255, t. 17.<br>Science N. S. 15: 940.<br>Torreya 4: 131 |
| × *emarginata.* | Hyattsville, Md. | 1 | Brainerd, Rhod. 8: 53.<br>House, Rhod. 8: 120, t. 71. |
| × *fimbriatula.* | Hempstead, Long Is., N. Y.<br>Staten Is., N. Y.<br>Fairfield, Conn. | 12 | Brainerd, Rhod. 8: 51, t. 67.<br>Distrib. 1910, Nos. 21 and 22.<br>Dowell, Bull. Torr. Cl. 37: 172 |
| × *lanceolata.* | Charles River Meadows, Dedham, Mass. | 1 | Forbes, Rhod. 11, 14. |
| × *papilionacea.* | Staten Is., N. Y.<br>Hempstead, N. Y. | 8 | Dowell, Bull. Torr. Cl. 37: 173, t. 14.<br>Distrib. 1910, No. 23. |
| × *pectinata.* | Hempstead, Long Is., N. Y.<br>Dayton, N. J.<br>Stratford, Conn.<br>Dedham, Mass. | 13 | Rhod. 8: 59, pl. 69. |
| × *sagittata.* | Riverdale, Md.<br>Staten Is., N. Y. | 2 | Brainerd, Rhod. 8: 51.<br>House, Rhod. 8: 120. |
| × *sororia.* | Fairfield, Conn. | 1 | |
| × *triloba.* | Milltown, N. J.<br>Stratford, Conn. | 5 | Rhod. 8: 55, where called "*V. palmata* × *septemloba.*" |
| *V. conspersa* × *rostrata.* | Plainfield, N. J.<br>Middlebury, Vt. | 5 | Distrib. 1910, No. 31. |
| *V. cucullata* × *fimbriatula.* | Newfane, Salisbury and Middlebury, Vt.<br>Jaffrey, N. H.<br>New York.<br>Connecticut.<br>New Jersey.<br>North Carolina. | 28 | Distrib. 1910, Nos. 34, 35, 36 and 37. |
| × *nephrophylla.* | Manchester, Vt. | 1 | |
| × *palmata.* | East Lyme, Conn. | 1 | |

| NAME | STATIONS | SHEETS IN HB. E. B. | WHERE PUBLISHED |
|---|---|---|---|
| *V. cucullata* × *papilionacea.* | Northampton, Mass.<br>Plainfield, N. J.<br>North Tacoma, D. C.<br>East Lyme and Southington, Conn.<br>Yonkers, N. Y. | 8 | Rhod. 8: 56. |
| × *pectinata.* | Woodmere, Long Is., N. Y. | 1 | |
| × *primulifolia.* | Woodmere and Rosedale, N. Y. | 2 | Rhod. 11: 115. |
| × *sagittata.* | Tinicum, Pa.<br>Montclair, N. J. | 7 | Rhod. 8: 52.<br>Distrib. 1910, No. 38. |
| × *septentrionalis.* | Silver Lake, Leicester, Vt.<br>Charlottetown, Prince Edward's Is. | 13 | Rhod. 6: 220.<br>Distrib. 1910, Nos. 39 and 40. |
| × *sororia.* | Widely distributed from Vermont to Wisconsin and south to Virginia. | 18 | Rhod. 6: 222.<br>Distrib. 1910, Nos. 41 and 42. |
| × *triloba.* | Lexington, Mass.<br>East Lyme, Conn.<br>Rochester, N. Y. | 8 | Rhod. 8: 56 as amended<br>Rhod. 11: 115. |
| × *viarum.* | Spontaneous in garden in 1912. | 2 | |
| *V. emarginata* × *fimbriatula.* | Washington, D. C.<br>New Brunswick, N. J.<br>Philadelphia, Pa. | 8 | Rhod. 8: 57. |
| × *Lovelliana.* | Muskogee, Okla. | 2 | |
| × *palmata.* | Eutaw Springs, S. C. | 1 | |
| × *papilionacea.* | Brookland, D. C.<br>Ivy Hill Cemetery, Philadelphia, Pa.<br>Milltown, N. J. | 4 | |
| × *sagittata.* | Brookland, D. C.<br>Chester Co., Pa.<br>Milltown, N. J. | 6 | |
| × *septemloba* House. | Gilmerton, Norfolk Co., Va. | 1 | Ined. |
| × *sororia.* | Carthage, Mo. | 1 | |
| × *Stoneana.* | Ivy Hill Cemetery, Philadelphia, Pa.<br>Ex horto 1905, 1907. | 1 | |
| × *triloba.* | Tryon, N. C. | 1 | |
| × *triloba* var. *dilatata.* | Westville, Okla.<br>Mena, Ark. | 4 | |

| NAME | STATIONS | SHEETS IN HB. E. B. | WHERE PUBLISHED |
|---|---|---|---|
| *V. emarginata* var. *acutiloba* × *fimbriatula*. | Brookland, D. C. | 1 | |
| var. *acutiloba* × *sagittata*. | North Tacoma, D. C. | 1 | |
| *V. emarginata* lobed form × *papilionacea*. | Brookland, D. C.<br>Ex horto 1905, 1906, 1907, 1910. | 5 | |
| *V. fimbriatula* × *latiuscula*. | Ft. Ethan Allen, Essex, Vt. | 10 | |
| × *palmata*. | Rochester, N. Y.<br>Mt. Tryon, N. C.<br>East Lyme, Conn.<br>Spring Valley, N. Y. | 10 | |
| × *papilionacea*. | Connecticut.<br>New Jersey.<br>New York.<br>Pennsylvania.<br>District of Columbia. | 22 | Rhod. 6: 218.<br>Rhod. 8: 54. |
| × *sagittata*. | Massachusetts.<br>Connecticut.<br>New Jersey. | 28 | Rhod. 8: 57, pl. 68. |
| × *septentrionalis*. | Maine.<br>Middlebury, Vt.<br>New Hampshire.<br>Massachusetts.<br>Prince Edward's Is. | 20 | Rhod. 6: 215, pl. 58. |
| × *sororia*. | Middlebury, Vt.<br>Hempstead, N. Y. | 4 | Rhod. 6: 218.<br>Distrib. 1910, Nos. 58 and 59. |
| × *triloba*. | Lexington, Mass.<br>New Hampshire.<br>Connecticut. | 9 | Rhod. 8: 53, pl. 70, for "*palmata*" real *triloba*. |
| *V. hirsutula* × *palmata*. | Plainfield, N. J. | 4 | Torr. Bull. 39: 96. |
| × *papilionacea*. | Philadelphia, Pa.<br>Ohio.<br>North Carolina.<br>Connecticut.<br>New Jersey.<br>District of Columbia. | 21 | Rhod. 9: 211.<br>Science, N. S. 25: 941.<br>Distrib. 1910, No. 66. |
| × *sagittata*. | Kenilworth, N. J.<br>Ex horto 1911. | 1 | |
| × *sororia*. | New Jersey.<br>Rockville, D. C.<br>Tryon and Biltmore, N. C. | 7 | |
| × *Stoneana*. | Hyattsville, Md.<br>Philadelphia, Pa.<br>Brookland, D. C. | 10 | Torr. Bull. 39: 96. |

| NAME | STATIONS | SHEETS IN HB. E. B. | WHERE PUBLISHED |
|---|---|---|---|
| *V. hirsutula* × *triloba.* | New Jersey.<br>District of Columbia.<br>Virginia.<br>North Carolina.<br>Morristown, Tenn. | 18 | Rhod. 8: 56, as "*V. palmata* × *villosa.*"<br>Torr. Bull. 39: 95. |
| × *triloba* var. *dilatata.* | Decatur, Ala.<br>Ex horto 1910. | 3 | |
| *V. Langloisii* × *rosacea.* | Crowley, La.<br>Ex horto 1910. | 1 | |
| *V. latiuscula* × *sororia.* | Lake Dunmore, Salisbury and West Rutland, Vt.<br>Williamstown, Mass. | 4 | |
| × *triloba.* | Salamanca, N. Y.<br>Ex horto 1910, 1912. | 16 | Torr. Bull. 39: 94. |
| *V. Lovelliana* × *papilionacea.* | Edgewood, Okla.<br>Ex horto 1910. | 3 | |
| *V. missouriensis* × *sororia.* | Kansas.<br>Missouri. | 2 | |
| *V. nephrophylla* × *papilionacea.* | Racine, Wis. | 4 | Distrib. 1910, Nos. 87 and 88. |
| × *pedatifida.* | Beulah, New Mex. | 0 | Torr. Bull. 40: 259. |
| × *sororia.* | Manchester, Vt. | 2 | |
| *V. odorata* × ———. | Bronx Park, N. Y.<br>Florida. | 2 | |
| *V. pallens* × *primulifolia.* | Staten Is., N. Y.<br>Seabrook, N. J. | 4 | Torr. Bull. 37: 177, pl. 18. |
| *V. palmata* × *papilionacea.* | Tryon, N. C.<br>Plainfield, N. J.<br>From Miss Kittridge 12.<br>Miss Angell 6.<br>Miss Kaufman 11. | 92 | Torr. Bull. 39: 85, pls. 5 and 6. |
| × *sagittata.* | Staten Is. and Rosedale, N. Y.<br>West Orange, N. J.<br>Haddenfield, N. J. | 3 | Rhod. 15: 115, No. 6. |
| × *sororia.* | Hamilton, Co., Ohio. | 1 | |
| × *triloba.* | Maryland Heights, Md.<br>East Lyme, Conn.<br>Orange, N. J.<br>*Bucks Co., Pa. | 20 | Torr. Bull. 39: 88, pls. 5, 6 and 7.<br>Distrib. 1910, No. 97. |
| *V. papilionacea* × *pedatifida.* | Yorkville, Ill. 64<br>Stark Co., Ill. 11 | 75 | Torr. Bull. 40: 249, pl. 15. |

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*25 miles north of Philadelphia.

| NAME | STATIONS | SHEETS IN HB. E. B. | WHERE PUBLISHED |
|---|---|---|---|
| *V. papilionacea* × *sagittata.* | Glastonbury, Conn.<br>New Brunswick, N. J.<br>Staten Is., N. Y.<br>Tinicum, Pa. | 11 | Rhod. 8: 54.<br>Distrib. 1910, No. 113. |
| × *sororia.* | Southeastern New York.<br>Ohio.<br>Wisconsin.<br>Kansas.<br>Missouri.<br>Louisiana. | 13 | Torr. Bull. 37: 178.<br>Distrib. 1910, No. 114. |
| × *Stoneana.* | Ivy Hill Cemetery, Philadelphia, Pa. | 9 | |
| × *triloba.* | Along the coast from East Lyme, Conn. to South Carolina. | 35 | Torr. Bull. 39: 90. |
| *V. pedatifida* × *sagittata.* | Peoria Co., Ill. | 20 | Torr. Bull. 40: 252, pl. 16. |
| × *sororia.* | Galva, Ill. 21<br>Ex horto Middlebury 115<br>Miscellaneous 18 | 154 | Torr. Bull. 40: 253, pl. 17. |
| *V. rosacea* × *sagittata.* | Crowley, La.<br>Ex horto 1910, 1911. | 3 | |
| *V. rostrata* × *striata.* | Cincinnati, O. | 2 | |
| *V. sagittata* × *sororia.* | Milwaukee, Wis.<br>Ex horto 1910, 1907. | 4 | Distrib. 1910, Nos. 142 and 143. |
| × *triloba.* | New Brunswick, N. J.<br>Ex horto 1906. | 6 | Rhod. 8: 54, [where for "*palmata*" read *triloba*].<br>Rhod. 15: 115. |
| *V. septentrionalis* × *sororia.* | Middlebury, Vt., 3 stations.<br>Arlington, Vt. | 6 | Rhod. 6: 221.<br>Distrib. 1910, No. 157. |
| *V. sororia* × *triloba.* | Orwell, Vt.<br>Connecticut.<br>Long Island, N. Y.<br>New Jersey.<br>Biltmore and Tryon, N. C. | 12 | Torr. Bull. 39: 92. |
| *V. Stoneana* × *triloba.* | Ivy Hill Cemetery, Philadelphia, Pa. | 14 | Torr. Bull. 39: 93.<br>Am. Naturalist 44: 231. |

## PUBLICATIONS OF EZRA BRAINERD ON VIOLA

1. Notes on New England violets I. Rhodora 6: 8-17. Jan., 1904.
2. Hybridism in the genus Viola. Rhodora 6: 213-223. Nov., 1904.
3. Notes on New England violets II. Rhodora 7: 1-8. Jan., 1905.
4. Notes on New England violets III. Rhodora 7: 245-248. Dec., 1905.
5. Hybridism in the genus Viola II. Rhodora 8: 6-10. Jan., 1906.
6. Hybridism in the genus Viola III. Rhodora 8: 49-60. Mar., 1906.
7. Behavior of the seedlings of certain violet hybrids. Science 25: 940-944. June, 1906.
8. Older types of North American violets. Rhodora 9: 93-98. June, 1907.
9. Dominance in the hybrids of Viola. Rhodora 9: 211-216. Nov., 1907.
10. V. chinensis in the eastern United States. Rhodora 10:38-40. Mar., 1908.
11. Viola. Gray Man. (ed. 7) 579-587. Mar., 1908.
12. Another hybrid between a white and a blue violet. Rhodora 11: 115-116. June, 1909.
13. The evolution of new forms in Viola through hybridism. Am. Naturalist 44: 229-236. Apr., 1910.
14. Five new species of Viola from the South. Bull. Torr. Club 37: 523-528. Nov., 1910.
15. Viola palmata and its allies. Bull. Torr. Club 37: 581-590. Dec., 1910.
16. Further notes on the stemless violets of the South. Bull. Torr. Club 38: 1-9. Jan., 1911.
17. The caulescent violets of the southeastern United States. Bull. Torr. Club 38: 191-198. Mar., 1911.
18. Violet hybrids between species of the palmata group. Bull. Torr. Club 39: 85-97. Apr., 1912.
19. Species of Viola. Britton & Brown's Illustrated Flora, Ed. 2, 2: 545-563. Apr., 1913.
20. Species of Viola. Small's "Flora" 800-807 (ed. 2). July, 1913.
21. Four hybrids of Viola pedatifida. Bull. Torr. Club 40: 249-260. June, 1913.
22. Is V. arenaria indigenous to North America? Rhodora 15: 106-111. June, 1913.
23. Notes on new or rare violets of northeastern America. Rhodora 15: 112-115. June, 1913.
24. V. septentrionalis in British Columbia. Rhodora 17: 70-71. Jan., 1915.
25. Flora of Rocky Mountains and adjacent plains. Rydberg 566-569. Jan.. 1918.

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University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# THE PROTEIN REQUIREMENTS OF DAIRY COWS

*By* J. L. HILLS, C. L. BEACH, A. A. BORLAND, R. M. WASHBURN,
G. F. E. STORY *and* C. H. JONES

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# BULLETIN 225: THE PROTEIN REQUIREMENTS OF DAIRY COWS

By J. L. Hills, C. L. Beach, A. A. Borland, R. M. Washburn, G. F. E. Story and C. H. Jones

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# I. INTRODUCTION

## The Personnel

The experimental feeding trials herein discussed were devised in 1906 by the first two named authors. Work was begun in December of that year and closed in May, 1919.

The relation of the several authors to this prolonged study has been as follows:

J. L. Hills, Director; collaborator in original plan; general oversight throughout the entire 13 years; advisory relations in connection with data computations; final collation and summation of all data; authorship of the entire manuscript.[1]

C. L. Beach, Animal and Dairy Husbandman, 1906-1908, and, since 1908, President of the Connecticut Agricultural College; formulation of the original plan of the trials; immediate oversight of their conduct during his incumbency; computations during the early stages of the trials.

R. M. Washburn, Animal and Dairy Husbandman, 1908-1911, later occupying an analagous position in the Minnesota Experiment Station and now engaged in commercial operations; immediate oversight of the trials during his incumbency; computations.

A. A. Borland, Animal and Dairy Husbandman, 1911-1915 and since that time head of the Department of Dairy Husbandry in the Pennsylvania State College; immediate oversight of the trials during his incumbency; computations—many of them final.

G. F. E. Story, Animal and Dairy Husbandman, 1915-1918 and since that time county agent in Worcester County, Mass.; immediate oversight of the trials during his incumbency; computations.

C. H. Jones, Chemist; in charge of all chemical work.

The authors acknowledge, with gratitude, the cooperation of:

W. J. Lamplough, B. S., computor for nearly three years, who in 1911-14 reviewed the figures from the very outset, correcting errors and in general painstakingly handling the immense amount of data.

E. R. Baker, B. S., computer for nearly two years, 1914-16, for careful supervision of the mathematics of the trials during his incumbency.

H. B. Ellenberger, Animal and Dairy Husbandman, 1918-, for helpful suggestions in connection with final presentation of the printed matter.

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[1] The writer acknowledges most helpful and stimulating suggestions received in the process of manuscript preparation from his former co-workers, President Beach and Professors Borland and Washburn, as well as from his present associate, Dr. Ellenberger.

C. J. Cosgrove, herdsman of the Station for 20 years, who day in and day out, almost without a day's absence from 1906 to 1916, fed the experimental animals and kept their barn records.

## THE TWELVE QUESTIONS

This twelve and one-half years' study of the protein requirements of dairy cattle was designed:—

1. To determine the effect upon the milk flow wrought by the long continued use of rations carrying either very low, or relatively low, or medium, or high digestible protein contents.

(*Pages 52-68; summarized, page 143.*)

2. To scrutinize the physical condition and health of cows fed on a uniform diet for a long series of years, with a view of determining whether or not either a relatively low digestible protein content on the one hand or a relatively high digestible protein content on the other was inimical to their continued well-being.

(*Pages 68-100; summarized, page 144.*)

3. To determine the relation which rations carrying very low, or low, or medium, or high digestible protein contents might bear to changes in the body weights of milking cows.

(*Pages 100-107; summarized, page 144.*)

4. To determine the immediate effects upon the milk flow of rations carrying either very low, low, medium or high digestible protein contents, as determined by means of trials of short duration.

(*Pages 107-109; summarized page 144.*)

5. To compare the results obtained in feeding trials conducted for many months or years with those secured in trials of shorter duration.

(*Pages 119-120; summarized, page 145.*)

6. To attempt to discover the relation between the digestible nutrients in the food and those accounted for in maintenance and milk flow, when rations were fed differing widely in their digestible protein contents.

(*Pages 120-128; summarized, page 145.*)

7. To review existing feeding standards in the light of the results thus secured.

(*Page 128; summarized, page 145; see also bulletin 226.*)

8. To observe the effect upon the quality of the milk flow secured when rations were fed which contained widely divergent digestible protein contents.

(*Pages 129-131; summarized, page 145.*)

9. To attempt to throw light upon the economics of milk and butter production when rations were fed which were decidedly unlike in their digestible protein contents.

*(Pages 131-137; summarized, page 145.)*

Incidentally the study was designed:

10. To add to the present stock of information as to the normal shrinkage in bovine milk flow.

*(Pages 137-139; summarized, page 146.)*

11. To secure further testimony as to the extent of the direct injury to the milk flow caused by abortion.

*(Pages 139-140; summarized, page 146.)*

12. To observe the effect upon the milk flow of abrupt changes in rationing.

*(Pages 141-142; summarized, page 146.)*

## THE CONSIDERATIONS ACTUATING THE TRIALS

Up to the time when this trial was begun, December 2, 1906, most feeding experiments with dairy animals made in this and other countries had been conducted for periods of a few weeks or months. The question often and naturally arose whether such short periods sufficed, whether they were calculated accurately to portray the physiological effect of any particular method of feeding or to indicate the food value of a nutrient. It has been shown that cows can accommodate themselves for considerable periods of time to a deficiency of certain elements in their food, these being supplied for the time being perhaps from body reserves. Babcock[1] observed that cows did not appear to be affected injuriously by the withdrawal of chlorin (salt) from the ration for short periods of time. "The cows exhibited an abnormal appetite for salt, after having been deprived of it for two or three weeks, but in no case did the health of the animal appear to be affected, until a much longer time had elapsed. This period of immunity varied with individual cows from less than a month to more than a year. In every case there was finally reached a condition of low vitality in which a sudden and complete breakdown occurred from which recovery was rapid if salt was supplied." [2]

Similarly, Haecker[3], reviewing the results of his investigations made prior to 1903 wherein rations with different nutritive ratios were fed, stated that "the rations having a nutritive ratio of 1 : 7.7 and 1 : 9.7

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[1] Wis. Sta. Rpt. 22, pp. 129-156 (1905).
[2] Ibid. p. 154.
[3] Minn. Sta. Rpt. 11, pp. 89-148 (1903); also Bul. 79 (1903).

respectively, were as effective in the production of milk, butterfat and milk solids as was the one having a nutritive ratio of 1 : 6.3."[4] However, as a result of further studies made during the winters of 1902-03 to 1904-05 in which a low protein ration, with a nutritive ratio of 1 : 9.5 supplying daily only 1.3 pounds of digestible protein, was fed in competition with a ration with a nutritive ratio of 1 : 6.5, supplying daily 1.94 pounds of digestible protein, Haecker[5] states that "so far as the yields of dairy products are concerned, there was little difference and it would ordinarily have been considered a negligible quantity."[6] A physical examination of the cows at the close of the second winter's feeding indicated, however, that the cows in the low protein group, while apparently in good health, were somewhat spare in flesh and thinner of skin than those receiving the higher amount of protein. During the third winter some of the cows on the low protein ration began to show a marked depression in physical tone. "When turned into the runway for water they lacked the alertness and activity shown by (the group fed 1.9 pounds of digestible protein). Their eyes were dull, coats harsh, and skins drawn hard to their bodies. They were slow in both eating and drinking, did not seem to relish their food, and showed in every movement a low state of vitality."[7] Four quarts of gluten feed were then substitued in the ration for four quarts of corn meal. This substitution raised the amount of digestible protein per cow per day from 1.333 pounds to 1.848 pounds and narrowed the nutritive ratio of 1 : 9.7 to 1 : 6.7. During the 49 days following the change the ten cows in the group made an average gain in weight of 72 pounds, while the increase of dairy products on a starch equivalent basis was only 0.05 pounds. "By narrowing the nutritive ratio of the ration to 1 : 6.7 the efficiency of the ration was increased enough to provide for the gain in body weight in addition to maintaining the yield of dairy products. It appears that with the cows that had been on the very low protein rations for from two to four winters, the impoverished condition of the nitrogenous substances of the body was so great that they were unable to give an increased yield of milk until the body had been restored to normal condition."[8]

Investigations at the Connecticut (Storrs) station[9] showed that an increase in the proportion of grain to roughage might exert as much of an effect upon the milk flow following a change in ration as did any increase and decrease in the amount of protein fed. In a somewhat similar fashion at the Minnesota station[10] a lessened protein supply was attended by a loss in weight of the animals concerned, although the milk and butterfat production were sustained. It is said that "whether the decrease in gain the second year and the loss in weight in the third year was due to the decrease in the protein supply or to some other cause, does not appear. But it is possible, it might be said quite probable, that it was due to the difference in the ratio of grain to roughage. During the winter 1901-2 two-thirds of the nutrients in the rations were provided by the roughage, while during the 1894-5 winter just half of the nutrients were in the roughage, and during the winter of 1895-6 less than half."[11]

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[4] Ibid. p. 126.
[5] Minn. Sta. Bul. 140 (1914).
[6] Ibid., p. 25.
[7] Ibid., p. 22.
[8] Ibid., pp. 26-27.
[9] Conn. (Storrs) Sta. Bul. 34 (1905).

In view of the results attained in the trials just cited, it was predetermined in the discussion held in 1906 which resulted in the shaping of the Vermont trials now under review, to make the proportion of grain to roughage as nearly uniform as possible for all animals, whether fed a ration carrying a low, a medium, or a high protein contents. The allowance of grain was based upon a unit yield of total solids in the milk flow. The grain mixtures were so constructed that their fiber, ash and total nutrient contents were practically identical. Since the quantity relations of concentrates to roughage in each ration were kept essentially uniform and since the ash, crude fiber and total nutrients contents were similarly standardized, the only variable factors in the rations were their protein, nitrogen-free-extract and fat contents. The first was the desired varient; the second necessarily decreased as the first increased; and it was impossible to keep the fat contents of the high protein ration on an absolute parity with that of the other two, since the only available high protein concentrates carried a considerable fat content. All this means, in brief, that, speaking broadly, one ration furnished just as much food as the others, just as much digestible nutrients as the others, that one ration carried the same relative proportions of roughage and concentrates as the others; that all conditions, physical and chemical, were so far as might be made uniform, save and except that of the quantity of digestible protein fed and, as a necessary corrollary, the quantity of digestible nitrogen-free-extract matter fed. When more protein was called for, it was secured by changing the grain mixture and not by increasing its amount.

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[10] Minn. Sta., Rpt. 11, pp. 89-148 (1903); also Bul. 79 (1903).
[11] Minn. Sta. Bul. 79, p. 126 (1903).

It is of interest to note, looking backwards, that the so-called "vitamines" or "water-" or "fat-solubles" contents of the several rations, seem to have been alike, at any rate within a reasonable degree of approximation. This factor was not taken into account when the trials were started. Indeed, its vital relationship to nutrition was not appreciated in 1906 as it is today. However, the devisers of the original scheme builded better than they knew in this respect. It seems quite safe to say that the effect of this particular factor upon the ultimate outcome may be disregarded.

## THE HERD; GROUPINGS; LIFE HISTORIES, ETC.

The herd, on December 2, 1906, consisted of 65 cows, two of which were registered Ayrshires, two registered Jerseys and the remainder grade Jerseys. Fifteen grade cows had been recently purchased. Nothing was known as to their milk and butterfat records. Six grade Holsteins were purchased in July, 1907. All further additions consisted of young animals raised from the better cows and introduced into the experimental trials from time to time as the older cows dropped out or as animals were withdrawn because of accident or failure to breed. The breeding of the Holsteins and Ayrshires was continued within their respective breed lines through the use of sires in neighboring herds, while that of the Jerseys was maintained by the use of registered Jersey bulls owned at the University Farm.

Abortion and sterility, temporary or permanent, have been disturbing factors. It was easy to reject the records following abortion and they have been excluded; but the great prolongation of the many lactation periods caused by failure to breed was unfortunate. However, so many cows were used, so many records were taken and figured in so many ways and the problem was attacked from so many points of view that the disturbing effects thus introduced can not materially have affected the outcome.

The average production of the experimental portions of the herd during these years has been much lower that it would have been had it been culled from time to time. However, since the older cows which had been eating one and only one ration for periods of from six to eleven years, or which had been alternating between two of the experimental rations for a similar length of time, were much more valuable from the standpoint of the trials than were younger cows, even though the latter were better producers, no animals were removed from the herd unless perchance they were no longer serviceable. Many a relatively or actually poor cow owed her long life to the exigencies of these prolonged trials. In fact one cow, used throughout this time in the maintenance studies reported upon in bulletin 226, did not produce a drop of milk during nearly nine years and was withdrawn in March, 1917, because of the after-effects of an attack of pneumonia. She has eaten, drank and been merry; she has toiled not, neither has she spun.

The 60 or more cows in the herd were divided at the outset into three groups, an equal number of animals being placed on low, on medium, and on high protein rations. Previous records were carefully scrutinized and, as far as possible, animals of the same age and of equal dairy capacity were grouped in sets of three, one of each group being placed on the low, on the medium and one on the high protein ration. Since little was known as to the productive capacities of the 15 cows purchased in the fall of 1906, these animals were studied from the standpoint of dairy conformation by the late Hon. C. M. Winslow, long time Secretary of the Ayrshire Breeders' Association, and by one of us (C. L. B.), and were distributed among the three groups on the basis of the combined judgments.

At all times throughout the long period of years the selection or rejection of a candidate for entrance to the trials was a matter of careful study as was, also, the dismissal of one which had served in her day and generation. In other words, the animals were chosen as it were by selective draft and dropped by a board of survey.

It should be noted that during the long course of these trials many cows necessarily were withdrawn. Death, old age, sickness, udder mishaps and many other causes conspired to this end. Substitutions were frequently made. However, the same care was taken in such events as at the outset of the trials to make certain as nearly as might be that adequate choices were made.

For example, by the close of the very first year havoc had been played with the carefully constructed groups which in December, 1906, started on the long journey in the continuous or alternating trials. No less than 14 of the 42 cows had failed to make good and were demoted. In the long continuous trials four aborted, one died, one proved barren and four were withdrawn for one reason and another; and in the lactation alternation trials one aborted, one became too lame to walk, one died and another was withdrawn. The first year's casualties were heavier than thereafter occurred; but they serve to indicate some of the difficulties met on the long, long trail which ran from 1906 to 1919. Of course not a single one of these records, or any other like them, figure in the final outcome.

## THE LOW PROTEIN GROUPS

The low protein groups of cows were fed a grain mixture designed to contain from 9.5 to 10 percent of digestible protein. The low protein ration had a nutritive ratio of 1: 8.6 and was intended to furnish approximately 1.5 pounds of digestible protein daily to the average cow yielding from 15 to 20 pounds of milk.

This low protein group of cows was subdivided into secondary groups, known as the "long continuous," "lactation alternation" and "short alternation" groups.

The cows constituting the *long continuous* sub-group ate the low protein grain mixture and accompanying roughages year after year throughout their working lives, when receiving any grain at all. Most of them were animals in early maturity, that is to say they had passed their years of increasing dairy power and seemed prepared to work for several years to come without material change and without being likely to become either better or worse as viewed from the standpoint of production.

The cows constituting the *lactation alternation* sub-group were fed for an entire lactation period on one of the rations, low protein for instance, for the next entire lactation period on one of the other rations, medium protein for instance, and then during the third entire lactation period on the ration fed during the first period, and during the fourth on that fed during the second, and so on. A lactation meant a lactation and not a year. It did not include the dry period which, as is shown on page 59, on the average was essentially alike in terms of its duration for each group. If a cow failed to breed readily, and milked for 15, 20 or 25 months, well and good so far as the purposes of the trial were concerned.; she was kept on the original ration for the full milking period. Matters were so arranged that approximately the same number of lactation alternation cows were fed upon low, medium and high protein rations at a given time. Most of these cows, like those which constituted the long continuous sub-group, were animals that had reached maturity but were still young enough to remain at a fairly constant level of productive power for a number of years.

The cows constituting the *short alternation* sub-group were changed from one ration, low protein for example, to one of the other rations, high protein for instance, and then back again every five weeks during the 30 weeks of the winter feeding season, beginning when the cows went into the barns in the fall and ceasing in the spring, just before the cows went to pasture. This group consisted of cows which were either so young that they would naturally be expected within a year or two to increase in dairy capacity, or of cows that had already passed their prime and were therefore not fitted for use in trials the successful conduct of which involved several years of normal milk production. In other words, this group comprised the animals that were either too young or too old to be included with safety in either the long continuous or lactation alternation groups.

This short alternation experiment was planned not only to test the question of protein requirements but also with a view of measuring the validity of short alternation experiments in general, using the long continuous and lactation alternation trials as a check. Naturally, if it can be determined with a fair degree of certainty that a carefully conducted short alternation feeding trial will be likely to afford essentially the same results as the longer and much more expensive tests, the former and more economical system is to be preferred. Much animal nutritional work has been done in the past with a comparatively small number of animals, fed for relatively brief periods, that is to say, from perhaps 12 to 30 weeks. The validity of the results secured by means of these short tests is now seriously questioned and a determination of the matter seemed to be called for. It does not appear too much to claim that the scope and extent of the trials now under survey are such that the outcome, so be it that it is properly interpreted, may be deemed to have settled the question. In other words, the short alternation trials were designed to furnish evidence upon which future plans might be based, as well as to throw light upon the central theme—that of the protein requirements of dairy cows.

### THE MEDIUM PROTEIN GROUPS

The medium protein groups of cows were fed a grain mixture designed to contain from 15.5 to 16 percent of digestible protein. The ration had a nutritive ratio of 1: 6.4 and was intended to furnish approximately 2 pounds of digestible protein daily to the average cow yielding from 15 to 20 pounds of milk.

In the same manner as was stated above in connection with the low protein group, the medium protein group was divided into three sub-groups; the long continuous lot, which received a medium protein ration continuously from the time of early maturity for a period of eight or more years or until accident, old age or sickness made its members ineligible; the lactation alternation lot which alternated between either medium and low or medium and high protein rations during succeeding lactations; and the short alternation lot which alternated between medium and low or between medium and high protein rations every five weeks during the 30 weeks of the winter feeding season.

### THE HIGH PROTEIN GROUPS

The high protein groups of cows were fed a grain mixture designed to contain from 21.5 to 22 percent of digestible protein. Their daily ration of grain and roughage had a nutritive ratio of 1: 5, and was meant to provide approximately 2.5 pounds of digestible protein to the average cow yielding from 15 to 20 pounds of milk. In the same manner as was stated above in connection with the low protein group, the high protein group was separated in three sub-groups; the long continuous lot which was fed the high protein grain mixture continuously for a long period of years; the lactation alternation lot, which changed from a high protein to either medium or to low protein rations during every other lactation period; and the short alternation lot which changed from a high to a low or a medium protein ration every five weeks during the 30 weeks of the winter feeding season.

### THE VERY LOW PROTEIN GROUPS

The results secured with the three groups above cited were sufficiently significant, when reviewed in 1914, to warrant the establishment of a sub-cellar trial. Consequently beginning that fall, a considerable number of cows were fed either continuously or in alternation with other rations a very low protein ration. The grain mixture carried only about 10 percent total protein—it was made as low as it could be and still be palatable—and 6.5 percent digestible protein. The daily mixture of grain and roughage had a nutritive ratio of 1 : 11.6 and provided approximately a pound of digestible protein to the average cow, yielding from 15 to 20 pounds of milk. No short alternation cows were used in this trial, only long continuous and lactation alternation subgroups being fed.

### NUMBERS FED

At the outset 21 cows were scheduled in three groups of seven each in the long continuous trial, 21 cows in three groups of seven each in the long alternation trial, and 21 cows in short alternation trials.

The numbers used varied from year to year. All told there were used in the long continuous feeding trials 42 different cows, 8, 12, 15 and 17 being fed respectively, the low, medium, high and very low protein rations. In the lactation alternation feeding trials, 34 different cows were used, 8, 10, 8 and 8 being fed alternately the low and medium protein, the low and high protein, the medium and high protein and the very low and low protein rations respectively. And there were 59 different cows used in the short alternation trials, some of them more than once, aggregating 127 different groups, fed during three to six five-week feeding periods. No less than 105 different cows in the aggregate were fed during nearly 450 years of cow life.

The total number and distribution of the lactations in the long continuous and lactation alternation trials were as follows:

Long continuous feeding trials: Low protein ration, 54; medium protein ration, 49; high protein ration, 40; very low protein ration, 27. Lactation alternation feeding trials: Long and medium protein rations, 40; low and high protein rations, 52; medium and high protein rations, 36; very low and low protein rations, 25; a total of 323 lactation periods. Not all of these were used, although the records of all were scrupulously kept and computed. All cases of abortion were excluded and a few instances of obvious abnormalities.

### LIFE HISTORIES

The following statement sets forth the life histories of the several cows used during all these years in the so-called long continuous and lactation alternation groups, up to and including June 30, 1919, when the trials were declared to be closed for the purposes of the present publication, and covering a period of twelve and a half years. The descriptions take up considerable room but seem desirable in order to complete the record. The statement covers the entire time during which a given cow was used. Each ration in the long continuous group is segregated. The "year" begins in each case in late October or early November, except that in 1906-07 it began on December 2.

These life histories are so stated that anyone who desires can readily determine in any case just how long the cow was in milk and just how long she was dry. Thus, for example, Aggie, who was a very shy breeder, in period I calved November 8, 1906, went dry July 7, 1908 and calved again October 4, 1908. Allowing two days for her to get regularly at milk, she was in milk 20 days in November, 578 from December 1, 1906 to July 1, 1908 and seven in July, a total of 605 days. No other cow was so long in milk as was Aggie. She was dry 24 days in July, 62 in August and September and calved October 4, a total of 90 days. The average lengths of the milking period and of the dry period of the average cow fed each ration, whether fed continuously or in alternation, stated in terms of days, appear on pages 59-60.

Vt. Aster, Vt. Ivis, Vt. Peony, Vt. Una, Vt. Una 2nd, Perusia Lady and Monetta were registered Jerseys; Zillah was a registered Ayrshire; Fyra, Elbaje and Catrina grade Holsteins; Catrina 2nd cross Holstein and Jersey; the remainder were grade Jerseys.

## LONG CONTINUOUS FEEDING—RECORDS OF LACTATIONS

### LOW PROTEIN RATION

| Name and date of birth | Entered trial | I* Calved | I* Dry | II† Calved | II† Dry | III‡ Calved | III‡ Dry | IV‡ Calved | IV‡ Dry | V Calved | V Dry | VI Calved | VI Dry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aggie ............'99 | 12- 2-06 | 11- 8-06 | 7- 7-08 | 10- 4-08 | 7- 4-10 | 8-14-10 | 5-26-12 | 7-26-12 | 10-15-13 | sold; age | | | |
| Ardelle ..........'03 | 12- 2-06 | 7- 9-06 | 7-23-07 | 8-15-07 | 7-15-08 | 8-21-08 | 10-17-09 | 11-28-09 | 9-12-10 | 11-26-10 | 10-15-11 | 12-12-11 | 4- 6-13 |
| | | 6- 6-13 | 5- 4-14 | 6-12-14 | 3-31-15* | 3-31-15* | 1-20-16 | 4-19-16 | 11- 1-17 | withdrawn | | | |
| Vt. Aster ........'05 | 4-27-07 | 4-27-07* | 3- 8-08 | 6- 3-08 | 6- 7-09* | 6- 7-09* | 9-12-10 | 1-23-11 | 11-18-11 | 1- 3-12 | 1-30-13 | 8- 9-13 | out |
| | | udder trouble 7-1-14; sold 10-31-14 | | | | | | | | | | | |
| Fyra ............'01 | 9- 1-07 | 9- 1-07 | 12- 1-08 | 4- 4-09 | 6-26-10 | 7- 4-10 | 7-15-11 | 8-10-11 | 6-23-12* | 6-23-12* | 5-10-13 | 6-15-13 | 5-27-14 |
| | | sold 10-31-14; age | | | | | | | | | | | |
| Grace ............'02 | 12- 2-06 | 5- 9-06 | 3- 4-07 | 4- 7-07 | 2-15-08 | 3-25-08 | 2- 6-09 | 4-12-09 | 3-19-10 | 7-27-10 | 4-21-11 | 7-18-11 | 3- 9-12 |
| | | 6-25-12 | 3- 1-13 | 6-23-13 | 5-25-14 | 8-18-14 | 10-30-15 | 12- 7-15 | 8-21-16 | withdrawn | | | |
| Kinky ...........'10 | 10-25-13 | 10-25-13 | 12-25-14 | 3- 4-15 | 5-28-16 | 7- 6-16 | 12-15-17 | farrow; barren | | | | | |
| Mab ............'05 | 5-17-07 | 5-17-07 | 5-26-08* | 5-26-08* | 6-20-09 | 7-27-09 | 6-19-10 | 7-24-10 | 8-13-11 | 9-12-11 | 8- 5-12 | 9-13-12 | 9- 7-13 |
| | | 10-19-13 | 12-29-14 | 2- 3-15 | 1-12-16 | transferred; maintenance trials | | | | | | | |
| Sheila ...........'02 | 2-24-07 | 2-24-07 | 1-13-08 | 5-18-08 | 4-23-09 | 7-24-09 | 5- 1-10* | 5- 1-10* | 12-25-10 | 4- 1-11 | 12-25-11 | 3- 6-12 | 1-25-13 |
| | | 3-24-13 | 2- 7-14 | 3-29-14 | 11-20-15 | sold; age | | | | | | | |

### MEDIUM PROTEIN RATION

| Name and date of birth | Entered trial | I* Calved | I* Dry | II† Calved | II† Dry | III‡ Calved | III‡ Dry | IV‡ Calved | IV‡ Dry | V Calved | V Dry | VI Calved | VI Dry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Angie ............'04 | 8-12-07 | 8-12-07 | 7-11-08 | 10-21-08 | 9- 5-09 | 2-25-10* | 10-16-10 | 4- 9-11 | 11- 6-11 | 3-14-12 | 1-18-13 | 4-18-13 | 3-30-14 |
| | | 6-15-14 | 10-31-14 | sold | | | | | | | | | |
| Elbaje ...........'02 | 2-10-08 | 2-10-08 | 6-20-09 | 7-27-09 | 9-13-10 | 10-26-10 | 9-22-11 | 12-24-11 | 7- 5-13 | 8-29-13 | 8- 2-14 | 9-21-14 | |
| | | discarded; leaky quarter | | | | | | | | | | | |
| Isadore ..........'06 | 10-18-12 | 5- 1-12 | 3-15-13 | 4-29-13 | 4-11-14 | 5-20-14 | 3-29-15 | transferred maintenance trials | | | | | |
| Karah ...........'09 | 12-15-12 | 12-15-12* | 12-31-13 | 1-22-14 | 11- 2-14 | | | transferred maintenance trials | | | | | |
| Lizzie Hexham....'99 | 12- 2-06 | 8-16-06 | 8-26-07 | 12- 4-07 | 5-10-09 | 9- 2-09 | 7-16-10 | 9-12-10 | 8-21-11 | 11- 5-11 | 9-29-12 | sold 11-2-12; age | |
| Mattie ...........'04 | 12- 2-06 | 10-24-06* | 7-21-07 | 10-18-07* | 8-28-08 | 10- 1-08 | 5-10-09 | 8-30-09* | sold 3-3-10; repeated abortions | | | | |
| Mu ..............'00 | 12- 2-06 | 3-16-06 | 7- 2-07 | 8-30-07 | 8-26-08 | sold 10-3-08 | | | | | | | |
| Rocket ...........'05 | 5-31-07 | 5-31-07 | 3-30-08 | 4-26-08* | 6-20-09* | 6-20-09* | 7-25-10 | 9-22-10 | 8-27-11 | 9-10-11 | 6-29-12 | 8-23-12 | 7-14-13 |
| | | 9- 1-13 | 8-15-14 | out 10-31-14 | | | | | | | | | |
| Ryllis ............'07 | 10-18-12 | 4-16-12 | 1-29-13 | 4-12-13 | 2- 7-14 | 4-26-14 | 2-19-15 | transferred; very low protein trials | | | | | |
| Slicker ...........'99 | 12- 2-06 | 10- 2-06 | 11- 4-07 | 1-15-08 | 3-22-09 | 8- 5-09 | 7- 3-10 | 7-29-10* | 7-17-11 | 10-22-11 | 9- 7-12 | sold; barren | |
| Vt. Ivis ..........'08 | 11-26-12 | 11-26-12 | 8- 2-13 | 11-12-13 | 5-23-14 | sold 10-14-14 | | | | | | | |
| Vt. Una ..........'00 | 5-29-08 | 5-29-08 | 4-29-09 | 7-11-09 | 5- 6-10 | 7-21-10 | 3-24-11 | 7- 3-11 | 5-10-12 | 8-18-12 | 10- 2-13 | 12-14-13 | |
| | | pus in one quarter; sold | | | | | | | | | | | |

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*Covers also period VII for Ardelle, Grace, Mab, Sheila, Angie, Rocket.

†Covers also period VIII for Ardelle, Grace, Mab, Sheila, Angie, Rocket.

‡Covers also periods IX and X for Ardelle, Grace, Mab, Sheila, Angie, Rocket.

| Name and date of birth | Entered trial | I Calved | I Dry | II Calved | II Dry | III Calved | III Dry | IV Calved | IV Dry | V Calved | V Dry | VI Calved | VI Dry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | HIGH PROTEIN RATION | | | | | | | |
| Cassandra ........'01 | 12- 2-06 | 8-27-06 | 2-23-08* | 2-23-08* | sold 7-16-08 | | | | | | | | |
| Catrina ..........'01 | 7- 6-07 | 7- 6-07 | 1- 1-08 | 2-12-08 | 1-25-09 | 3- 4-09 | 6-18-10 | 9- 7-10 | died 9-30-10; wire in diaphragm and heart | | | | |
| Cloedah ..........'07 | 10-18-12 | 8-22-12 | 10- 1-13 | 11-21-13 | died 12-2-13; inflammation of udder | | | | | | | | |
| Electa ...........'09 | 11-10-12 | 11-10-12 | 11-22-13 | 1-24-14 | out 10-31-14 | | | | | | | | |
| Fizzy ............'10 | 10-17-13 | 9-14-13 | 9- 1-14 | transferred; maintenance trials | | | | | | | | | |
| Hepsy ............'06 | 10-18-12 | 8-26-12 | 7- 5-13 | 9-13-13 | one quarter useless; discarded | | | | | | | | |
| Hilda ............'01 | 12- 2-06 | 10-11-06 | 1-28-08 | 5-15-08 | 2-16-09 | 6- 4-09 | sold 5-23-10; ugly cow, difficult to milk | | | | | | |
| Madam ...........'05 | 5-16-07 | 5-16-07 | 4-19-08 | 7- 5-08 | 8-23-09 | 11-12-09 | 7-17-10 | 10-10-10 | 8- 5-11 | 11-11-11 | 8- 4-12 | | |
| | | sold 9-18-12; poor cow | | | | | | | | | | | |
| Peggy ............'05 | 8-18-07 | 8-18-07 | 6-11-08* | 6-11-08* | 7-18-09 | 8-31-09 | 9-18-10 | 11-11-10 | 6-15-11* | 6-15-11* | died 7-9-11; wire in liver | | |
| Phoebe ...........'09 | 10-18-12 | 1-22-12 | 11-25-12 | 1-16-13 | 10-27-13 | 12-16-13 | 9-12-14 | transferred to very low protein trials | | | | | |
| Rosel ............'98 | 7-24-07 | 7-24-07 | 7-24-08 | 12- 3-08 | 2-26-10 | 4-28-10 | 10-21-11 | 12-28-11 | sold 11-2-12; age | | | | |
| Vt. Peony ........'08 | 10-18-12 | 10- 9-12 | 10-19-13 | 1- 5-14 | 11- 6-14 | transferred to very low protein trials | | | | | | | |
| Vic ..............'10 | 10-25-13 | 10-25-13 | 12-13-14 | | | transferred to very low protein trials | | | | | | | |
| Yuba..............'99 | 12- 2-06 | 8-10-06 | 12-30-07 | 3-27-08 | 2- 2-09* | 2- 2-09* | 2-21-10 | 5-12-10 | 5-13-11 | 8-23-11 | 7-26-12 | 10- 2-12 | 8- 5-13 |
| | | sold 10-10-13; age; one quarter lost | | | | | | | | | | | |
| Zeta .............'99 | 12- 2-06 | 7-25-06 | 3- 6-07 | 9- 5-07 | 7-13-08 | 9-14-08 | 8-15-09 | 12-18-09 | 12- 4-10 | 4- 1-11 | 4- 6-12 | 5-23-12 | 3-31-13 |
| | | died 4-30-13; abortion treatment | | | | | | | | | | | |
| | | | | | | VERY LOW PROTEIN RATION | | | | | | | |
| Granny ..........'11 | 10-30-14 | 9- 6-14 | 7-10-15 | 9-25-15 | 3-27-17 | withdrawn; barren | | | | | | | |
| Katydid ..........'10 | 11- 9-14 | 11- 8-14 | 8-21-15 | 11- 6-15 | 10-26-16 | 12- 1-16 | 8- 9-17 | 11- 5-17 | 3-20-19 | 4-20-19 | 6-30-19* | | |
| Phoebe ..........'09 | 12-14-14 | 12-11-14 | 10- 3-15 | 1- 2-16 | 10- 5-16 | sold 6-24-17; barren | | | | | | | |
| Rena ............'11 | 4- 7-15 | 4- 4-15 | 3- 4-16 | 4-25-16 | 3-26-17 | 4-13-17 | 1-15-18 | 2-15-18 | 2-14-19 | 3-25-19 | 6- 5-19† | | |
| Ryllis ...........'07 | 7- 3-15 | 6-18-15 | 3-31-16 | 6- 3-16 | 3-24-17 | 5-17-17 | 3- 9-18 | 5-22-18 | 2-20-19 | 5-20-19 | 6-30-19* | | |
| Vt. Peony ........'08 | 2- 8-15 | 2- 4-15 | 1-13-16 | 8- 5-16 | 7-13-17 | 9-23-17 | 9- 5-18 | 10-28-18 | 6-30-19 | | | | |
| Vic ..............'10 | 2-19-15 | 2-16-15 | 1-16-16 | 2-26-16 | 2-26-17 | 4- 5-17 | 5- 1-18 | 6- 5-18 | 6- 5-19 | | | | |

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*Close of trial.

†Trial closed for this cow.

## Lactation Alternation Feeding—Records of Lactations

### LOW AND MEDIUM PROTEIN RATIONS

| Name and date of birth | Entered trial | I Calved | I Dry | II Calved | II Dry | III Calved | III Dry | IV Calved | IV Dry | V Calved | V Dry | VI Calved | VI Dry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | | Medium | | Low | | Medium | | Low | | Medium | |
| Crystal ..........'02 | 12- 2-06 | 10-24-06 | 12- 5-07 | 12-24-07 | 11-12-08 | 12- 6-08 | 11- 3-09* | 11- 3-09* | 8- 8-10 | 9-27-10 | 8-28-11 | 9-27-11 | 8- 1-12 |
| | | 9- 5-12 | 9- 8-13 | 10-18-13 | 10-15-14 | dropped from trial | | | | | | | |
| Elizabeth ........'00 | 12- 2-06 | 12- 1-06 | 11-24-07 | 2-17-08 | 11- 7-08 | 1-22-09 | 11- 7-09 | 2- 1-10 | 12-10-10 | 1-25-11 | 10-13-11 | 1- 7-12 | 12-23-12 |
| | | 1-31-13 | 2- 1-14 | 5-11-14 | out 10-31-14; age | | | | | | | | |
| Zillah ............'02 | 2-17-07 | 2-17-07 | 12-17-07 | 2- 5-08 | 11-28-08 | 1-11-09 | 3- 1-10 | 5- 2-10 | 3-11-11 | 4-29-11 | 6-22-12 | 8-10-12 | 7-27-13 |
| | | 8-16-13 | 5-25-14 | 7-25-14 | out 10-31-14 udder trouble | | | | | | | | |
| | | Medium | | Low | | Medium | | Low | | Medium | | Low | |
| Edith ............'98 | 12- 2-06 | 12- 2-06 | 1-21-09 | 2- 2-09 | 9-15-10 | 11-12-10 | sold 11-2-12; barren; almost dry | | | | | | |
| Goldfinch ........'01 | 12- 2-06 | 9-13-06 | 9-27-07 | 10-31-07 | 12-14-08 | 1- 9-09 | 10-29-10* | 10-29-10* | sold 9-18-12; barren | | | | |
| Ladybird .........'00 | 12- 2-06 | 10- 5-06 | 10-28-07 | 1- 8-08 | 10-30-08 | 12-31-08 | 11- 7-09 | 12-17-09 | 11- 1-10 | 12-24-10 | 11- 4-11 | 1-10-12 | 3- 2-13 |
| | | 4-29-13 | 4- 6-14 | 6-10-14 | out 10-31-14; age | | | | | | | | |
| Laura B .........'07 | 10-18-12 | 3-23-12 | 2-22-13 | 3-10-13 | 2-23-14 | 4- 6-14 | 3-30-15 | 5-26-15* | 3- 8-16* | 3- 8-16* | | | |
| | | transferred to very low protein trials | | | | | | | | | | | |
| Theta ............'08 | 10-27-12 | 10-27-12 | 9-30-13 | 10-25-13 | 11-23-14 | transferred to very low protein trials | | | | | | | |

### LOW AND HIGH PROTEIN RATIONS

| Name and date of birth | Entered trial | I Calved | I Dry | II Calved | II Dry | III Calved | III Dry | IV Calved | IV Dry | V Calved | V Dry | VI Calved | VI Dry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | | High | | Low | | High | | Low | | High | |
| Alta .............'97 | 12- 2-06 | 10-26-06 | 9-28-07 | 11-11-07 | 11-27-08 | 2- 4-09 | 11-25-09 | 1-20-10 | 1-12-11 | 2-12-11 | 4-26-12 | 6-29-12 | |
| | | sold 11-2-12; age | | | | | | | | | | | |
| Cherry ...........'00 | 12- 2-06 | 11- 8-06 | 12-19-07 | 2-15-08 | 4- 8-09 | 6-24-09 | 4-28-10 | 6-26-10 | 7- 6-11 | 9- 7-11 | 7-11-12 | 8-28-12 | 7-10-13 |
| | | 9-10-13 | 8- 6-14 | transferred to very low protein trials | | | | | | | | | |
| Lena ............'03 | 1-11-07 | 1-11-07 | 10-15-07 | 1-17-08 | 12- 1-08 | 1- 8-09 | 6-20-10 | 8-17-10 | 7-20-11 | 8-26-11 | | | |
| | | milk fever and pneumonia; sold 11-6-11 | | | | | | | | | | | |
| Vie ..............'02 | 12- 2-06 | 11-13-06 | 1-12-08 | 4-10-08 | 7-27-09 | 9-22-09 | 6-16-10* | 6-16-10* | 6-24-11 | 7-30-11 | 6-29-12 | 8-10-12 | 8-10-13 |
| | | 9- 2-13* died; abortion treatment | | | | | | | | | | | |
| Dot ..............'09 | 10-18-12 | 9-13-12 | 6-12-13 | 8-12-13 | 6-25-14 | 8- 5-14 | 6- 4-15 | 9- 3-15 | 5- 6-16 out 9-2-16 | | | | |
| | | High | | Low | | High | | Low | | High | | Low | |
| Dewdrop .........'00 | 12- 2-06 | 10-22-06 | 9- 1-07 | 10-22-07 | in milk | 1-28-09 | 11-25-09 | 1-20-10 | 3-16-11 | 4-19-11 | 7- 5-12 | 7-30-12 | 1- 1-14 |
| | | 3-10-14 died 8-9-14 | | | | | | | | | | | |
| Hester ...........'01 | 12- 2-06 | 10-15-06 | 12- 8-07 | 1-25-08 | 12- 1-08 | 1-13-09 | 7- 4-10 | 9-17-10 broken hip; sold 8-24-11 | | | | | |
| Kate .............'00 | 12- 2-06 | 10- 7-06 | 12-28-07 | 2-28-08 | 11-13-08* | 11-13-08* | 10-17-09 | 12-27-09 | 11-28-10 | 12-27-10 | 11-19-11 | 1-17-12 | 12-15-12 |
| | | 2- 3-13 | 12- 7-13 | 2-18-14 | out 10-31-14; age | | | | | | | | |
| Monetta ..........'06 | 11- 5-12 | 11- 5-12 | 11-30-13 | 1- 4-14 | 12-30-14 | transferred to very low protein trials | | | | | | | |
| Santa Rosa .......'99 | 1-18-07 | 1-18-07 | 12- 1-07 | 1-20-08 | 11- 1-08 | 1-17-09 | 1- 6-10* | 1- 6-10* | 10-22-10 | 1-13-11 | 10-14-11 | 12-15-11 | |
| | | sold 5-20-12; udder trouble; barren | | | | | | | | | | | |

MEDIUM AND HIGH PROTEIN RATIONS

| Name and date of birth | Entered trial | I Calved | I Dry | II Calved | II Dry | III Calved | III Dry | IV Calved | IV Dry | V Calved | V Dry | VI Calved | VI Dry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Medium | | High | | Medium | | High | | Medium | | High | |
| Avis ............’00 | 12- 2-06 | 10- 2-06 | 11- 7-07 | 12- 8-07 | 10-22-08 | 1- 2-09 | 4-28-10 | 7- 1-10 | 5-18-11 | 6-28-11 | 7-10-12 | 8-28-12 | 9- 4-13 |
| | | 11-21-13 out 10-30-14; age | | | | | | | | | | | |
| Augusta ..........’06 | 9- 9-10 | 9- 9-10 | 7- 6-11 | 9-13-11 | 7-11-12 | 8-29-12 | 5-22-13* | 5-22-13* | 2- 5-14 | 4-16-14 | 3-14-15 | | |
| | | transferred to maintenance trials | | | | | | | | | | | |
| Fatima ..........’02 | 12- 2-06 | 9-28-06 | 11- 4-07 | 3- 2-08 | 12-31-08 | sold 1-1-09 | | | | | | | |
| Tansy ...........’03 | 12- 2-06 | 11-11-06 | 10-23-07 | 1-25-08 | 12-27-08 | 1-14-09 | 12-29-09 | 2-12-10 | 11-21-10 | 1-17-11 | 2-18-12 | 4-14-12 | 5-10-13 |
| | | 6-19-13 out 10-31-14; barren | | | | | | | | | | | |
| Vinegar ..........’09 | 1-15-13 | 1-15-13 | 1-23-14 | 3- 4-14 | 2- 8-15 | transferred to maintenance trials | | | | | | | |
| | | High | | Medium | | High | | Medium | | High | | Medium | |
| Doris ...........’01 | 12- 2-06 | 9-12-06 | 11-15-07 | 1-23-08 | 10-25-08 | 1-18-09 | 3-10-10 | 4-19-10 | 5- 6-11 | 6-27-11 | 5- 3-12 | 7-25-12 | 6-23-13 |
| | | 10-16-13 out 13-31-14;barren | | | | | | | | | | | |
| Mildred ..........’03 | 4-13-07 | 4-13-07* | 2-28-08* | 2-28-08* | 2-10-09* | 2-10-09* | 2-22-10 | 4-29-10 | 7-17-11 | 10- 2-11 | 8- 4-12 | 9-13-12 | 7-30-13 |
| | | 10-12-13 out 10-30-14 | | | | | | | | | | | |
| Perusia Lady .....’04 | 12- 2-06 | 10-27-06 | 11-28-08 | 12- 8-07* | 7-14-08 | sold 10——08; inferior cow and barren | | | | | | | |
| VERY LOW AND LOW PROTEIN RATIONS | | | | | | | | | | | | | |
| | | Very low | | Low | | Very low | | Low | | | | | |
| Alice ............’11 | 1-30-15 | 1-28-15 | 1- 7-16 | 1-15-16 | 3-24-17 | 4-21-17 | 3-14-18 | 4-11-18 | 6-30-19 | | | | |
| | | Very low | | Low | | | | | | | | | |
| Cherry ...........’00 | 10-29-14 | 10-18-14 | 12-31-15 | 4- 9-16 | 10-26-16 | dropped from trial; nearly dry | | | | | | | |
| | | Very low | | Very low | | Very low | | | | | | | |
| Janet ............’11 | 1-30-15 | 1-28-15 | 8-21-16 | 9-21-16* | 12-25-17 | 1-10-18 | 3- 1-18 | withdrawn | | | | | |
| | | Low | | Very low | | Very low | | Very low | | Very low | | | |
| Vt. Una 2nd ......’12 | 12-19-14 | 12-16-14 | 10-17-15 | 12-11-15 | 10- 1-16 | 10-20-16 | 9-13-17 | 11-10-17 | 4- 2-19 | 6- 3-19 | 6-30-19 | (trial closed) | |
| | | Very low | | Low | | Low | | Very low | | Low | | | |
| Catrina 2nd ......’10 | 12-17-14 | 12-15-14 | 11- 1-15 | 12-17-15 | 12-31-16 | 2-11-17 | 9-29-17 | 12-28-17 | 10-25-18 | 1- 2-19 | 6-30-19 | (trial closed) | |
| | | Low | | Low | | Very low | | | | | | | |
| Laura B ..........’07 | 5-30-15 | 5-26-15 | 3- 8-16* | 3- 8-16* | 6-29-17 | 8-11-17 | 6- 5-19 | | | | | | |
| | | Very low | | | | | | | | | | | |
| Monetta ..........’06 | 5-14-15 | 5-11-15 | 3-29-17 | dropped from trial; barren | | | | | | | | | |
| | | Very low | | Low | | Low | | Low | | | | | |
| Theta......... ...’08 | 1-28-15 | 1- 7-15 | 10-24-15 | 1-17-16 | 10-14-16 | 2- 3-17 | 10- 5-17 | 12-25-17 | 2- 1-18 | dead | | | |

The following statement lists the cows used during the seven years, 1913 to 1919, inclusive, in the short alternation trials by names, ages and dates of calving prior to their entrance upon and subsequent to their exit from the trials. These always covered a term of 30 weeks from October to May. The "periods" were five weeks long, but the experimental data was taken only on the last three weeks of each period, although weights, analyses, etc., were made covering the entire time. The scheme used was in all respects similar to that long in vogue at this Station, as set forth many times in its earlier reports. The beginning and closing dates of each trial period were: 1906-07, December 2-May 26; 1907-08, October 25-May 21; 1908-09, October 23-May 20; 1909-10, October 22-May 19; 1910-11, Oct. 21-May 18; 1911-12, October 20-May 16; 1912-13, October 18-May 15; 1913-14, October 17-May 14.

Minta Bella, Lady Perusia, Monetta, Vermont Peony, Vermont Ivis and Vermont Una 2nd were registered Jerseys; Lanta and Lanta B. registered Ayrshires; Catrina a grade Holstein; the remainder were grade Jerseys.

SHORT ALTERNATION TRIALS—COMPARISON OF LOW AND HIGH PROTEIN RATIONS

| Season | Name | Dropped | Calved | Calved | Season | Name | Dropped | Calved | Calved |
|---|---|---|---|---|---|---|---|---|---|
| 06-07 | Ceres | 1891 | 5-16-06 | 6- 4-08 | 09-10 | Haidee | 1896 | 6-24-08 | Farrow |
| | Euclina | 1898 | 1- 3-07 | 2- 2-08 | | Monetta | 12- 2-06 | 9- 9-09 | 9-19-10 |
| | Maid Marian | 1893 | 8-14-06 | 6- 3-07† | | Stephanie | 1897 | 9- 1-09 | 5-23-10† |
| | Mermaid | 1896 | 9-19-06* | 7- 6-08 | | Zirconia | 1898 | 12-25-09 | 2-27-11† |
| | Minta Bella | 1891 | 11-25-06 | 6-24-07† | 10-11 | Cloedah | 12-26-07 | 8-30-10 | 9- 2-11 |
| | Vivian | 1894 | 8-25-06 | 6- 3-07† | | Dell R. | 1-10-09 | 2- 5-11 | 2- 5-12 |
| | Yemassee | 1895 | 2-24-06* | 12-10-07 | | Helen M. | 12-10-07 | 7-25-10 | Farrow† |
| 07-08 | Elsa | 1896 | 12-26-07 | 2-20-09† | | Monetta | 12- 2-06 | 9-19-10 | 9- 6-11 |
| | Euclina | 1898 | 2- 2-08 | 5-22-08† | | Phoebe | 2- 4-09 | 1-13-11 | 1-22-12 |
| | Haidee | 1896 | 7-11-06 | 6-24-08 | | Vermont Peony | 1- 3-08 | 9-13-10 | 10-18-11 |
| | Judith | 1897 | 2-17-07 | 10——08‡ | | Zirconia | 1898 | 12-25-09 | 2-27-11† |
| | Lady Perusia | 1894 | 3- 5-06 | 3-13-08† | 11-12 | Evelyn | 7- 5-07 | 9-27-11 | 9-29-12 |
| | Lucerne | 1893 | 6-25-07 | 4-11-08† | | Frances | 1897 | 4- 4-11 | Farrow |
| | Mermaid | 1896 | 9-19-06* | 7- 6-08 | | Hepsy | 11-30-06 | 9- 4-11 | 8-26-12 |
| | Mona | 1896 | 8- 9-07 | 8-28-08 | | Nesbit | 7-24-07 | 10-21-11 | 12-22-12 |
| | Stephanie | 1897 | 9- 2-07 | 8-14-08 | | Phoebe | 2- 4-09 | 1-22-12 | 1-16-13 |
| | Yemassee | 1895 | 12-10-07 | Farrow† | | Theta | 5-18-08 | 11- 6-11 | 10-27-12 |
| | Zirconia | 1898 | 12- 7-07 | 1-16-09 | | Vermont Ivis | 5-29-08 | 12-17-11 | 11-26-12 |
| 08-09 | Chi | 1895 | 7-19-08 | 8-31-09 | 12-13 | Catrina | 9- 7-10 | 9-24-12 | 9-26-13 |
| | Gamma | 1898 | 1- 1-09 | 5-13-10 | | Dell R. | 1-10-09 | 2- 5-12 | 5- 3-13 |
| | Haidee | 1896 | 6-24-08 | Farrow | | Gamma | 1898 | 9-26-12 | 7- 2-13† |
| | Stephanie | 1897 | 8-14-08 | 9- 1-09 | | Katydid | 8-15-09 | 1-25-13 | 11- 8-14 |
| | Zirconia | 1898 | 1-16-09 | 12-25-09 | 13-14 | Dorcas | 2-17-10 | 8-21-13* | 9-24-14* |
| 09-10 | Chi | 1895 | 8-31-09 | 5-23-10† | | Emma | 8-26-11 | 8-23-13* | 11-15-14* |
| | Gamma | 1898 | 1- 1-09 | 5-13-10 | | Vermont Una 2nd | 7-13-11 | 10-11-13 | 12-16-14 |

SHORT ALTERNATION TRIALS—COMPARISON OF MEDIUM AND HIGH PROTEIN RATIONS

| Season | Name | Dropped | Calved | Calved | Season | Name | Dropped | Calved | Calved |
|---|---|---|---|---|---|---|---|---|---|
| 06-07 | Frances | 1897 | 1- 6-07 | 9-12-08 | 07-08 | Chi | 1895 | 7-14-07 | 7-19-08 |
| | Gamma | 1898 | 10-18-06 | 12-10-07 | | Frances | 1897 | 1- 6-07 | 9-12-08 |
| | Haidee | 1896 | 7-11-06 | 6-24-08 | 08-09 | Euclina | 1898 | 2- 2-08 | 5-22-08† |
| | Mona | 1896 | 7-17-06 | 8- 9-07 | | Hepsy | 11-30-06 | 12- 6-08* | 8-11-10 |
| | Rebecca | 1898 | 9-13-06 | Farrow | | Isadore | 11-25-06 | 10-26-08 | 2-17-10 |
| | Stephanie | 1897 | 1-25-06 | 9- 2-07 | | Mermaid | 1896 | 7- 6-08 | 8-15-09 |

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*Aborted. †Sold. ‡Killed; enlarged liver.

SHORT ALTERNATION TRIALS—COMPARISON OF MEDIUM AND HIGH PROTEIN RATIONS—continued

| Season | Name | Dropped | Calved | Calved | Season | Name | Dropped | Calved | Calved |
|---|---|---|---|---|---|---|---|---|---|
| 09-10 | Hepsy | 11-30-06 | 12- 6-08* | 8-11-10 | 11-12 | Dot | 4-12-09 | 10-16-11 | 9-13-12 |
| | Mary | 7-17-06 | 8-28-09 | Farrow | | Effa | 7- 6-08 | 11- 8-11 | 7- 2-12* |
| | Mermaid | 1896 | 8-15-09 | 5-23-10† | | Electa | 1-14-09 | 11-30-11 | 11-10-12 |
| | Nesbit | 7-24-07 | 4- 8-09 | 6-18-10 | | Katydid | 8-15-09 | 12-19-11* | 1-25-13 |
| | Ryllis | 5-15-07 | 4-22-09 | 5-22-10 | | Monetta | 12- 2-06 | 9- 6-11 | 11- 5-12 |
| | Lanta 2nd | 11-22-07 | 2-10-10 | 5-23-11 | | Vermont Peony | 1- 3-08 | 10-18-11 | 10- 9-12 |
| 10-11 | Hepsy | 11-30-06 | 8-11-10 | 9- 4-11 | | Vinegar | 12-19-09 | 12-23-11 | 1-15-13 |
| | Lanta 2nd | 11-22-07 | 2-10-10 | 5-23-11 | 12-13 | Alice | 4-19-11 | 12- 6-12 | 12- 3-13* |
| | Mary | 7-17-06 | 8-28-09 | Farrow | | Kinky | 7- 1-10 | 9-11-12* | 10-25-13 |
| | Nesbit | 7-24-07 | 6-18-10 | 10-21-11 | | Vic | 1902 | 9-19-12 | 10-25-13 |
| | Ryllis | 5-15-07 | 5-22-10 | 5- 7-11 | 13-14 | Cora | 11-11-11 | 11-13-13 | 1-25-15* |
| | Theta | 5-18-08 | 10-13-10 | 11- 6-11 | | Janet | 7-23-10 | 11-23-13* | 1-28-15 |
| | | | | | | Tops | 9-12-11 | 9-15-13* | 11-27-15* |

SHORT ALTERNATION TRIALS—COMPARISON OF LOW AND MEDIUM PROTEIN RATIONS

| Season | Name | Dropped | Calved | Calved | Season | Name | Dropped | Calved | Calved |
|---|---|---|---|---|---|---|---|---|---|
| 06-07 | Chi | 1895 | 2- 2-06 | 7-14-07 | 10-11 | Electa | 1-14-09 | 12-21-10 | 11-30-11 |
| | Elsa | 1896 | 8-13-06 | 12-26-07 | | Evelyn | 7- 5-07 | 8- 4-10 | 9-27-11 |
| | Judith | 1897 | 11-25-06 | 2-17-08 | | Frances | 1897 | 1- 4-11 | Farrow† |
| | Lady Perusia | 1894 | 3- 5-06 | Farrow† | | Laura B. | 12- 8-07 | 8-12-10 | 3-23-12 |
| | Lanta | 7-31-02 | 8-12-06 | 11-23-07 | | Vermont Ivis | 5-29-08 | 1-13-11 | 12-17-11 |
| | Lucerne | 1893 | 4-29-06 | 6-25-07 | | Witch | 2- 7-09 | 10-21-10* | Farrow† |
| | Zirconia | 1898 | 10-29-06 | 12- 7-07 | 11-12 | Cloedah | 12-26-07 | 9- 2-11 | 8-22-12 |
| 07-08 | Gamma | 1898 | 12-10-07 | 1- 1-09 | | Dell R. | 1-10-09 | 2- 5-12 | 5- 3-13 |
| 08-09 | Augusta | 11-24-06 | 11-13-08* | 9- 9-10 | | Isadore | 11-25-06 | 3- 3-11 | 5- 1-12 |
| | Frances | 1897 | 9-12-08 | 1-29-10 | | Karah | 11-12-09 | 12- 7-11* | 12-15-12* |
| | Mona | 1896 | 8-28-08 | 9- 2-09 | | Lanta 2nd | 11-22-07 | 5-23-11 | 8-20-12 |
| | Yemassee | 1895 | 12-10-07 | 5-20-09† | | Ryllis | 5-15-07 | 5- 7-11 | 4-16-12 |
| | Zuke | 1906 | 6-28-08* | 7-31-09 | | Gamma | 1898 | 5-13-11 | 9-26-12 |
| 09-10 | Augusta | 11-24-06 | 11-13-08 | 9- 9-10 | 12-13 | Effa | 7- 6-08 | 7- 2-12* | 6- 4-13 |
| | Evelyn | 7- 5-07 | 6-24-09 | 8- 4-10 | | Fizzy | 4-24-10 | 9-24-12 | 9-14-13 |
| | Frances | 1897 | 1-29-10 | 1- 4-11 | | Janet | 7-23-10 | 7-22-12* | 11-23-13 |
| | Mona | 1896 | 9- 2-09 | 5- 4-10† | | Rena | 12-23-10 | 12- 1-12* | 3-24-14 |
| | Vermont Ivis | 5-29-08 | 1- 4-10* | 1-13-11 | 13-14 | Alice | 4-19-11 | 12- 3-13* | 1-28-15 |
| | Zuke | 1906 | 7-31-09 | 5-23-10† | | Granny | 7-11-10 | 8-13-13* | 9- 6-14 |
| 10-11 | Effa | 7- 6-08 | 8-28-10 | 11- 8-11 | | Maud | 8-23-11 | 5-30-13* | 10-12-14 |

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*Aborted. †Sold.

Of course all the cows were not in use all the time. Records made when drying off were not used, nor as a rule those made in the first week or two of freshening. Some were used for three periods, some five and some six, according to circumstances.

## THE FEEDS

### THE ROUGHAGES

Obviously in a feeding trial extending over so long a period of time and necessitating the use of so large a number of animals, it was quite impossible to feed a uniform quality of roughage. Seasonal variations were disturbing factors. Drought sometimes cut short the pasture feeding period and so parched the meadows that there was no rowen crop. In some years the hay contained much clover and in other years less. In some years it was cut early and secured undamaged; in others damage occurred. It was usually a good grade of early cut stock hay of mixed grasses, largely timothy, with a fair to good proportion of red and alsike clovers. The University Farm carries a large number of cows in proportion to its area, and hence it became necessary occasionally to buy hay. Quite often oats cut green formed a small proportion of the hay ration. The rowen crop, too, was fed each year that it was harvested, being usually a better quality of hay than the first cutting. The silage necessarily varied one year as compared with another. Sanford seed was always sown. The crop matured to the glazing stage perhaps half the time. The crop was large enough some years to last the year round, silage being fed as a soiling crop and as pasture supplement. In other years it did not suffice to carry the herd through the summer and divers soiling crops were grown (green rye, peas and oats, alfalfa and millet). One year the corn crop was very light and the silage supply was exhausted in March and, consequently, corn fodder was purchased and a "mock silage" fed to good advantage.[1] Apple pomace was fed each fall, sometimes freely, sometimes less freely, according to the size of the apple crop. However, in all cases all the cows were treated alike in respect to roughage consumption. Consequently it is thought that these inevitable variations in the quality and quantity of roughage have not materially affected the general outcome. All roughages were sampled weekly and analyzed at least twice a year. Dry matter determinations were made weekly.

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[1] See Vt. Sta. Bul. 170, pp. 126-127 (1913).

The amounts fed daily were approximately the same for each of the three groups of cows. The maximum amount of silage fed daily was 40 pounds, which was given to a few cows yielding exceptionally large amounts of milk. Cows yielding a little above the herd average received 30 pounds; average cows 25 pounds; and those slightly below the average, 20 pounds daily. The hay was apportioned according to appetite, from 8 to 20 pounds daily being fed to all animals, whether in milk or not, according to size and condition. The amount of "orts," or uneaten food, left by the different animals was closely watched and formed the chief guide in determining the amount of roughage to feed each cow.

The situation as to the necessity for pasturage and its effect upon the outcome are set forth in full on pages 41-42.

The following table shows the proportions of total food, i. e., hay, silage, concentrates; of total dry matter; of digestible dry matter; and of digestible protein, derived from the three sources, i. e., the two roughages and the concentrates in each ration as fed to the cows in the two main groups, the last three items being derived by the use of average figures as displayed in the tables on pages 36-37.

PERCENTAGES OF TOTAL FOOD, TOTAL DRY MATTER, DIGESTIBLE DRY MATTER AND DIGESTIBLE PROTEIN (TOTAL = 100) DERIVED FROM

| Ration | Total food | | | Total dry matter | | | Digestible dry matter | | | Digestible protein | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hay | Silage | Grain | Hay | Silage | Grain | Hay | Silage | Grain | Hay | Silage | Grain |
| | % | % | % | % | % | % | % | % | % | % | % | % |
| | Long continuous feeding trials | | | | | | | | | | | |
| Very low ... | 15.4 | 19.9 | 64.7 | 38. | 32.6 | 29.4 | 33.8 | 31.1 | 33.9 | 35.9 | 25.5 | 38.6 |
| Low ........ | 17.5 | 22.9 | 59.6 | 40.6 | 27.9 | 31.5 | 36.9 | 28. | 35.1 | 31.3 | 17.7 | 51. |
| Medium ..... | 17.1 | 22.1 | 60.8 | 39.7 | 29.9 | 31.4 | 36. | 29. | 35. | 23.5 | 14. | 62.5 |
| High ....... | 18.1 | 22.7 | 59.2 | 39.8 | 27.5 | 32.7 | 35.8 | 27.3 | 37. | 18.6 | 10.6 | 70.8 |
| | Lactation alternation trials | | | | | | | | | | | |
| Very low ... | 15.8 | 20.4 | 63.8 | 38.4 | 31.8 | 29.8 | 34.2 | 31.3 | 34.4 | 36.8 | 24.4 | 38.8 |
| Low ........ | 18.2 | 23.7 | 58.1 | 41.2 | 26.7 | 32.1 | 37.4 | 26.8 | 35.7 | 31.6 | 16.8 | 51.6 |
| Medium ..... | 17.7 | 23.2 | 59.1 | 40.7 | 27.5 | 31.8 | 37. | 27.5 | 35.4 | 24. | 13.3 | 62.7 |
| High ....... | 18.2 | 23.1 | 59.7 | 40.3 | 27.1 | 32.6 | 36.1 | 26.8 | 37.1 | 18.9 | 10.4 | 70.7 |

Expressed in terms of fractions, the following statement indicates the situation in a general way.

| | Total food | | | Total dry matter | | | Total digestible matter | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hay | Silage | Grain | Hay | Silage | Grain | Hay | Silage | Grain |
| Very low ration... | 1-6— | 1-5 | 5-8+ | 3-8 | 1-3 | 3-10 | 1-3+ | 3-10 | 1-3+ |
| Low, medium, high rations..... | 1-6 | 2-9 | 3-5— | 2-5 | 1-4+ | 1-3— | 3-8 | 1-4+ | 3-8— |

It will be observed:

(1) That the proportions of grain to roughages were kept closely alike in the different groups. This is especially true in the main trials in which the low, medium and high protein rations were fed, the spread being but 3½ percent.

(2) That the proportions of total and of digestible dry matters derived from the three sources in the four rations were closely similar, especially in the trials in which the low, medium and high protein rations were fed, in which the spreads were respectively 3 and 4½ percents.

(3) That the proportions of digestible protein derived from the three sources in the four rations changed profoundly, as was to be expected, the averages being for the very low, low, medium and high protein rations in the order stated: Hay ⅜—, 3⁄10, ¼—, ⅕—; silage silage ¼, ⅙, 1⁄7, 1⁄10+, contentrates ⅜+, ½+, ⅝, 7⁄10.

It would seem as if the attempt so to formulate the rations that essential uniformity would be secured as to the proportions of roughages and concentrates, not only in the gross but as to the total and digestible dry matter contents, had been attained within a reasonable limit of error.

## THE CONCENTRATES

Much careful thought was given to the determination of the nature of the concentrates which should be used and of the proportions in which they should be employed. As finally selected, wheat bran and ground oats formed the basis of each mixture, the other constituents being added in such kinds and amounts as would furnish the desired composition. The four mixtures were so formulated as to contain as nearly as might be the same amounts of ash, digestible crude fiber, and total digestible nutrients, the only varients being the digestible protein contents and, as a necessary sequence, the digestible nitrogen-free-extract matter contents. The grain mixtures were made up as follows:

| Protein contents | Wheat bran | Ground oats | Corn-and cob-meal | Hominy feed | Gluten feed | Cotton-seed meal | Linseed meal |
|---|---|---|---|---|---|---|---|
| Very low .. | 100 | 100 | 300 | 100 | ... | ... | ... |
| Low ...... | 300 | 200 | ... | 200 | ... | ... | ... |
| Medium .. | 300 | 175 | ... | ... | 100 | 125 | ... |
| High ..... | 200 | 100 | ... | ... | ... | 200 | 200 |

Wheat bran and ground oats were common to all four mixtures; hominy, gluten feed and corn and cob-meal, all corn products, were found in the low, medium and the very low protein mixtures; while cottonseed meal was common to the medium and high protein mixtures.

Multitudinous chemical analyses were made during the twelve and one-half years. Each individual concentrate entering into the grain mixtures was analyzed as well as the separate mixtures after they had been compounded ready for use, samples being taken either weekly or bi-weekly. The average, maximum and minimum analyses of the several roughages, concentrates, grain mixtures, etc., together with a statement of their contents of manurial ingredients and digestible nutrients are shown in tables on pages 36 to 37.

It is evident that the requirements as stated above for the four grain mixtures were met; that the digestible ash, fiber and total organic nutrient contents were practically identical. The very low protein mixture contained on the average 6.36 percent of digestible protein; the low protein mixture, 9.76 percent; the medium, 15.77 percent; and the high, 21.78 percent, with corresponding differences in digestible nitrogen-free-extract contents.

The concentrates used, wheat bran, ground oats, hominy feed, gluten feed, cottonseed meal, old process linseed meal and corn and cob-meal, were bought in the open market. No attempt was made to confine purchases to definite commercial brands, in view of the fact that brand names in the feed trade are apt to mean very little. However, standard materials were bought and, it is believed, received.[1] During a portion of one year new process linseed meal was used, since old process goods could not at that time be found on sale in Vermont.

### THE DIGESTION COEFFICENTS

The digestion coefficients were derived in the main from Lindsey's compilation.[2] Obviously the validity of the results of such an experiment as is now being discussed depends in a controlling degree upon the accuracy of the digestion coefficients. Since Lindsey's compilation was more nearly up-to-date in 1906 than any other list then available, and since a large proportion of the data was of New England origin, it was thought that they would meet the conditions of the trials more accurately than any other available coefficients.

The writers can not help but feel somewhat uncertain, particularly as to the ash and fiber coefficients of the roughages; but they are comforted by the reflection that the final determination made by two of them (J. L. H. and C. L. B.) was the result of much careful comparison and correspondence and that they did their best.

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[1] The debasement of cottonseed meal of late years as compared with its earlier quality made it somewhat difficult to maintain the full protein percentage of the high ration toward the end.

[2] Mass. Sta. Rpt. 18, pp. 224-248 (1906).

| | Dry matter | Ash | Protein | Crude fiber | Nitrogen-free-extract | Ether extract |
|---|---|---|---|---|---|---|
| V'y low protein grain mixture | 75.8 | 33 | 62.7 | 44.5 | 83.3 | 81.7 |
| Low protein grain mixture.. | 71.7 | 28.4 | 73.9 | 43.3 | 77.6 | 77 |
| Med. protein grain mixture.. | 72.2 | 26.4 | 79.6 | 40.3 | 76.1 | 76.4 |
| High protein grain mixture. | 74 | 23.6 | 82.6 | 41.1 | 75.6 | 82.1 |
| Wheat bran ................ | 66 | 25 | 77 | 39 | 71 | 63 |
| Ground oats[1] .............. | 70 | 25 | 78 | 26 | 76 | 83 |
| Hominy feed ............... | 82 | 37 | 65 | 67 | 89 | 92 |
| Cottonseed meal[2] .......... | 79 | 24 | 84 | 35 | 78 | 94 |
| Gluten feed[3] ............... | 86 | 37 | 85 | 76 | 89 | 83 |
| Linseed meal[4] .............. | 79 | 21 | 89 | 57 | 78 | 89 |
| Corn and cob meal[3] ........ | 79 | 37 | 52 | 45 | 88 | 84 |
| Corn silage ................ | 64 | 33 | 53 | 68 | 66 | 71 |
| Green hay .................. | 64 | 32 | 48 | 56 | 66 | 52 |
| Oats and peas ............. | 70 | 48 | 74 | 60 | 67 | 64 |
| Millet (sundried) .......... | 65 | 52 | 60 | 68 | 67 | 64 |
| Green barley .............. | 67 | 42 | 72 | 61 | 71 | 60 |
| Green alfalfa ............... | 61 | 40 | 74 | 43 | 72 | 39 |
| Green millet ............... | 66 | 55 | 63 | 70 | 67 | 62 |
| Oat hay ................... | 54 | 39 | 53 | 51 | 55 | 60 |
| Mixed hay ................. | 60 | 47 | 57 | 60 | 61 | 50 |
| Apple pomace[5] ............. | 72 | 55 | 0 | 61 | 84 | 47 |
| Rowen hay................. | | | Same as mixed hay | | | |

### NATURE OF THE PROTEIN CONTENTS

It has been many times and from many sources indicated of late that all digestible proteins are not alike; that digestible protein derived from wheat, for example, is notably lacking and unable, per se, to maintain production; that zein, gelatin and other single proteins by themselves are unable to maintain growth without the admixture of other proteins. In all the trials discussed in this bulletin and in No. 226, the sources of digestible protein were many—mixed hay, silage, apple pomace, sundry soiling crops, wheat bran, oats, hominy feed, gluten feed, cottonseed and linseed meals. Now the sources of digestible protein in the concentrates in the very low and low protein rations are identical; but it was necessary to introduce into the medium ration a different material in somewhat small quantities and into the high protein ration two other ingredients in large quantities. The approximate derivations of the digestible protein contents of the several rations was as follows:

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[1] European coefficients.
[2] Ash, from U. S. Dept. Agr., Of. Exp. Sta., Bul. 77 (1900).
[3] Ash; assumed hominy.
[4] Ash; assumed flax meal, Mass. Sta. Rpt. 13, p. 51 (1900).
[5] Mass. Sta. Rpt. 16, p. 68 (1904).

| Ration | Hay | Silage | Bran | Oats | Cob meal, hominy meal, gluten feed | Cottonseed | Linseed |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % |
| Very low .. | 36.4 | 25. | 11.3 | 8.7 | 18.7 | ... | ... |
| Low ...... | 31.5 | 17.3 | 26.6 | 13.9 | 10.7 | ... | ... |
| Medium ... | 23.8 | 13.7 | 19.3 | 8.8 | 11.9 | 22.5 | ... |
| High ...... | 18.7 | 10.5 | 10.4 | 4. | ... | 29.2 | 27.2 |

From hay, silage, bran and oats were derived 81.4, 89.3, 65.6 and 43.6 percents of the digestible proteins in the four rations; and from hay, silage, bran, oats and corn, 100, 100 and 77.5 percents of the digestible protein of three of the four rations. It probably would have been better to have used gluten meal, a corn product, in place of cottonseed and linseed meals, had it been available; but it was not available. Its manufacture as such had been discontinued some years before the trials began. Only within the last two or three years has it reappeared in Eastern markets. Furthermore, at the time these trials were inaugurated, the distinction between proteins as to their feeding values was not appreciated as fully as it it today.

The writer knows of no evidence based on experimental trials which would tend to prove that in any of these rations the cows were not supplied with a sufficient variety of digestible protein. Aside from that in the hay, every cow received digestible protein derived from wheat, oats and corn (in silage or concentrates). In other words, every cow ate protein derived from four sources. The cows fed the medium and high protein rations ate this nutrient derived from five or six sources. It is conceivable, though the writer does not deem it probable, that the large proportion of the digestible protein in the high protein rations derived from cottonseed and linseed meals disadvantaged the cows eating these rations as compared with those fed the other two. If so, the fact has yet to be determined by further experimental work; at any rate no conclusive evidence to the contrary as come to the writer's attention.

No attempt was made to determine the true protein and non-protein contents of the several roughages and concentrates. Non-proteins existed, but their presence was ignored, total nitrogen being calculated as crude protein and the standard digestion coefficients used, as suggested by Armsby.[1] The proportions of true proteins to non-proteins in the several rations apparently were not materially unlike. If this is so, the error thus introduced, if any, was of little moment.

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[1] U. S. Dept. Agr., Bu. An. Ind., Bul. 139 (1911).

## THE ASH CONTENTS

The ash content of the various rations seemed sufficient in each case. At any rate, no one of them was deemed at the outset, or is thought now in the retrospect, to have been decidedly lacking or to have been a limiting factor. The utilization of the digestible crude ash in the food in the milk flow rarely exceeded 30 percent and in only a single instance exceeded 40 percent (see tables A to F folded in opposite page 64). This fact would apparently amply justify the statement made in the preceding sentence. Indeed, Forbes and his co-workers[1] who, if anyone, are entitled to express an opinion touching bovine usage of the ash constituents of food—say "that the mineral metabolism of the wellfed, heavily milking cow is not intimately and directly dependent upon the mineral nutrients of the ration, but that its character is determined under normal conditions, first by the inherited impulse to secrete milk, second, by the mineral nutrient reserves of the animal body and only third by the food supply."

## THE FEEDING SYSTEM

The cows were fed twice daily, the concentrates first being offered, followed by the hay and silage, all in carefully weighed amounts. For the sake of convenience the low, medium, high and very low protein grain mixtures were known respectively as the red, white, blue and green mixtures. The feed bins in which they were stored were labeled accordingly with red, white, blue and green cards. The cart from which the feed was dealt out to the cows was separated into compartments appropriately painted. The cards which were affixed to each manger, designating the amount of grain to be fed each animal, were either red, white, blue or green, thus indicating the kind of grain to be fed. These were changed from time to time as the amounts to be fed varied as the lactation advanced. Larger cards of other colors were used to indicate the amount of hay (yellow) and silage (light brown) to be fed. This color scheme was adopted for the reason that it seemed likely to minimize the possibility of error, and it enabled the use of ordinary farm help in feeding. It should be remarked, however, through nine of the long series of years, the feeding was done by one experienced man together with a helper, and that the essential accuracy of stable work was frequently and carefully checked.

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[1] Ohio Sta. Bul. 330, p. 103 (1918).

A daily report blank was filled out by the herdsman, in order to furnish records of calving, service, cows sick or off-feed, cases of garget or other udder trouble, dates and weights of grain mixing, changes in the feed of the different individuals in the herd, etc. In order to guard against error and against possible oversight on the part of the herdsman, such as failure to record changes in feed of any individual cow upon the daily sheets, a separate record of the kind and amount of grain, hay and silage apportioned to each animal in the herd was made once a week by an independent observer. This record was taken from the grain, hay and silage cards in front of the manger of each cow and was compared with the daily report.

The food left uneaten by each animal was weighed and recorded at frequent intervals, and the amount of this weighed-back material deducted from the total weight of the food fed. It was always small in quantity, appetites being carefully estimated. It is recognized that the composition of this rejected material may not have been the same as that of the entire ration; but it would have involved an immense amount of work to have analyzed these residues and to have deducted their nutrients. Furthermore in a general way the nature of these residues was noted and recorded. Since the quantity thus left was always small and the digestion coefficients applicable to this coarse material difficult to determine, the procedure above outlined was deemed sufficiently accurate to serve the purpose.

### APPORTIONMENT OF GRAIN

Each cow was fed grain according to the amount of milk solids she produced. At intervals of four to six weeks grain allowances were reapportioned according to the weights of total solids produced during the previous week. During the winter about seven pounds of grain were fed as a rule to a cow that produced an average amount of total solids. Cows yielding a greater or less amount of total solids than the average for the herd were fed correspondingly greater or less amounts of grain. For instance, if the average daily yield of total solids for the herd was 3.6 pounds per cow, then each cow yielding 3.6 pounds of milk solids per day was entitled to and usually received seven pounds of grain; cows yielding 2.7 pounds of total solids were fed three-fourths of that amount or 5.25 pounds and those yielding 4.8 pounds one and a third times seven pounds, or 9.3 pounds daily.

This procedure may be made the more clear if explained by example. Let us assume that 45 cows were in milk. Their individual total weekly milk yields, multiplied by the individual total solid percentages, furnish their individual weekly total solid yields in terms of pounds. These being added and used as a divisor of 45 (cows) × 7 (days) × 7 (pounds grain per average cow), or 2205, the final result indicates the pounds of grain to be fed daily per pound total solids in a given cow's milk. If, for example, the gross total solid yield for the week was 929.4 pounds then 2205 ÷ 929.4 = 2.3725; and 2.3725 pounds of grain are to be fed daily for every pound of daily yield of total solids.

Cow A. 3.4 pounds × 2.3725 = 8.1 pounds grain.
Cow B. 3.05 pounds × 2.3725 = 7.2 pounds grain.
Cow C. 2.94 pounds × 2.3725 = 7. pounds grain.
Cow D. 2.15 pounds × 2.3725 = 5.1 pounds grain.

From the time when the cows were turned to pasture in late May and until about the middle of July when the pasture became short and dry, one-half the usual grain allowance was given, the amounts fed being kept in strict proportion to the total solids yields as was the case during the other ten months of the year.

## THE ANALYTICAL CONTROL

### MILK SAMPLING AND ANALYSES

The milking was done by the regular farm help, with the addition of such student labor as could profitably be used. One man devoted his entire attention at milking time to weighing and sampling.

During the earlier years the milk yielded by the cows other than those fed in short alternation was sampled for seven consecutive milkings every two weeks, and the composite samples tested for their total solids and fat contents. Every other sample, or one each month, was subjected to complete chemical analysis. Later the system was slightly changed so that two composite samples were taken in five weeks. The first sample, which included the last seven milkings at the end of the second week, was tested for its total solids and fat contents; the second, which comprised the last seven milkings at the end of the fourth week, was subjected to complete analysis. During the winter feeding trials, the milk of the cows listed in the short alternation trials was sampled continuously during the experimental portion of each period. During the remainder of the year the same method of sampling was pursued as was employed with the animals on the long time feeding trials.

The fat contents were determined by duplicate Babcock tests; the total solid contents were determined by triplicate Quevenne lactometer readings (using different instruments) and the application of the Richmond slide rule; the casein and albumin (together) were determined by multiplying the nitrogen content by the conventional factor 6.25[1]; the ash was determined by incineration; and the milk sugar was determined by difference. Actual total solid determinations would have been worth while but it was impracticable to make them. However, so vast was the number of samples and determinations that it is quite certain that the averages correctly represent the facts.

### FEED SAMPLING AND ANALYSES

Samples were taken continuously throughout the year. The grain was sampled every two weeks, samples being taken not only of the grain mixtures but of each ingredient. All these were analyzed for dry matter and composited for semi-annual (or more frequent) complete analyses. The analyses of the ingredients served as a check on the mixing and on the accuracy of the sampling and of the analyses

The roughages were sampled every week, three separate samples of silage being taken and two of hay. Large samples of several pounds each were taken and placed in a special gas-heated drying device capable of handling a dozen or more samples, weighing approximately 75 to 100 pounds. Moisture determinations were made on each sample individually, after which semi-annual (or more frequent) complete chemical analyses were made of composite samples, composed of equal amounts of roughage taken from the separate original samples. The standard official methods were employed. All samples, subsequent to the determination of their dry matter contents, were stored under vermin proof conditions and, prior to analyses, the entire masses of each were ground in the power mills of a local wholesale drug house.

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[1] When these trials were instituted, the 6.25 conversion factor was in universal usage. Some time after they were under way, the 6.38 conversion factor was officially adopted for milk albuminoids, although, as is pointed out in several food chemistry manuals of recent date, the 6.25 factor is still quite commonly employed. A large amount of computational work was done before the 6.38 factor was officially adopted and much more, through inadvertence, thereafter; hence the 6.25 factor was used throughout the great mass of computations. The differences involved by its usage are not large in any case. Anyone who desires to re-compute can readily do so by multiplying by 1.02 the casein and albumin figures in the great tables A to F which are folded in opposite page 64 or in the tables on pages 126 and 129, whether these figures are stated in terms of percentage or in terms of pounds; and by subtracting the increments thus obtained from the milk sugar figures, whether stated as percentages or as pounds. The average percentage figures will be increased or decreased, as the case may be, by 0.07 and the average weight figures by 0.01.

AVERAGE, MINIMUM AND MAXIMUM ANALYSES—ROUGHAGES AND CONCENTRATES

| | | No. of analyses | Chemical composition | | | | | | | | | | Digestible nutrients | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Water | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract | Nitrogen | Phosphoric acid | Potash | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract |
| | | | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % |
| Hay | Ave. | 50 | 12.91 | 87.09 | 6.11 | 8.02 | 28.60 | 42.31 | 2.05 | 1.28 | 0.47 | 1.84 | 51.43 | 2.88 | 4.58 | 17.11 | 25.90 | 1.03 |
| | Min. | | 8.21 | 84.13 | 5.03 | 5.19 | 23.35 | 34.34 | 1.61 | 0.83 | 0.28 | 0.58 | 50.49 | 2.37 | 2.96 | 12.00 | 20.95 | 0.80 |
| | Max. | | 15.87 | 91.79 | 8.82 | 11.81 | 32.99 | 47.11 | 2.81 | 1.89 | 0.63 | 3.40 | 55.07 | 4.15 | 6.73 | 19.79 | 30.47 | 1.45 |
| Summer hay | Ave. | 12 | 24.90 | 75.10 | 4.87 | 6.55 | 23.50 | 38.30 | 1.88 | 1.05 | 0.37 | 1.47 | 45.32 | 2.22 | 3.68 | 14.02 | 23.52 | 0.94 |
| | Min. | | 11.83 | 34.58 | 2.37 | 3.06 | 10.25 | 18.00 | 0.90 | 0.49 | 0.17 | 0.42 | 22.13 | 0.76 | 1.47 | 5.74 | 11.88 | 0.47 |
| | Max. | | 65.42 | 88.17 | 6.99 | 9.97 | 30.57 | 45.22 | 2.59 | 1.60 | 0.49 | 2.80 | 52.87 | 3.29 | 5.68 | 18.34 | 27.58 | 1.30 |
| Oat hay | Ave. | 11 | 14.46 | 85.54 | 7.29 | 8.06 | 27.54 | 40.38 | 2.27 | 1.29 | 0.60 | 2.22 | 46.25 | 2.84 | 4.27 | 14.11 | 22.20 | 1.31 |
| | Min. | | 12.84 | 83.70 | 5.53 | 5.94 | 24.42 | 35.98 | 1.66 | 0.95 | 0.41 | 0.93 | 45.20 | 2.16 | 3.15 | 12.46 | 19.79 | 1.00 |
| | Max. | | 16.30 | 87.16 | 8.38 | 9.41 | 31.97 | 45.01 | 3.14 | 1.51 | 0.80 | 3.25 | 47.23 | 3.27 | 4.99 | 16.31 | 24.75 | 1.88 |
| Rowen hay | Ave. | 11 | 18.60 | 81.40 | 7.16 | 9.91 | 23.12 | 38.60 | 2.64 | 1.59 | 0.58 | 1.92 | 48.84 | 3.28 | 5.65 | 13.85 | 23.54 | 1.40 |
| | Min. | | 12.94 | 74.50 | 6.02 | 8.12 | 19.39 | 34.99 | 1.99 | 1.30 | 0.44 | 1.32 | 44.70 | 2.83 | 4.63 | 11.63 | 21.34 | 1.00 |
| | Max. | | 25.50 | 87.06 | 8.11 | 11.03 | 26.91 | 42.53 | 3.75 | 1.76 | 0.79 | 2.80 | 52.24 | 3.81 | 6.29 | 16.15 | 25.94 | 1.98 |
| Soiling crops | Ave. | 11 | Too diverse in quality to analyze; used in relatively small amounts | | | | | | | | | | | | | | | |
| | Min. | | 15.12 | 20.85 | 2.63 | 3.31 | 4.82 | 8.93 | 0.47 | 0.53 | 0.10 | 0.28 | 12.72 | 1.24 | 2.11 | 2.07 | 6.43 | 0.18 |
| | Max. | | 79.15 | 84.88 | 8.38 | 12.63 | 23.17 | 45.65 | 2.08 | 2.02 | 0.57 | 3.02 | 55.17 | 3.68 | 9.35 | 14.73 | 30.66 | 1.33 |
| Silage | Ave. | 56 | 76.77 | 23.23 | 1.53 | 2.00 | 5.98 | 13.12 | 0.60 | 0.32 | 0.13 | 0.40 | 14.88 | 0.51 | 1.06 | 4.06 | 8.85 | 0.43 |
| | Min. | | 66.19 | 17.82 | 1.07 | 1.31 | 4.84 | 8.10 | 0.36 | 0.21 | 0.09 | 0.18 | 11.41 | 0.35 | 0.69 | 2.99 | 5.35 | 0.26 |
| | Max. | | 82.18 | 33.81 | 2.60 | 2.98 | 7.35 | 19.45 | 1.05 | 0.48 | 0.23 | 0.63 | 21.64 | 0.86 | 1.49 | 5.00 | 13.55 | 0.75 |
| Apple pomace | Ave. | 13 | 79.20 | 20.80 | 0.78 | 1.27 | 3.20 | 14.29 | 1.26 | 0.23 | 0.08 | 0.18 | 14.97 | 0.43 | ... | 1.95 | 12.01 | 0.51 |
| | Min. | | 82.37 | 17.63 | 0.60 | 1.06 | 2.75 | 11.42 | 0.84 | 0.17 | 0.05 | 0.16 | 12.69 | 0.33 | ... | 1.19 | 9.60 | 0.34 |
| | Max. | | 75.74 | 24.26 | 0.97 | 1.69 | 4.14 | 17.19 | 1.61 | 0.27 | 0.10 | 0.26 | 17.46 | 0.53 | ... | 2.52 | 13.35 | 0.66 |
| High protein grain mixture | Ave. | 27 | 10.57 | 89.43 | 5.73 | 26.47 | 8.91 | 42.37 | 5.95 | 4.24 | 2.13 | 1.37 | 66.17 | 1.35 | 21.87 | 3.66 | 32.03 | 4.88 |
| | Min. | | 12.44 | 87.56 | 5.23 | 23.88 | 7.29 | 40.00 | 4.98 | 3.82 | 1.66 | 1.11 | 64.80 | 1.35 | 19.73 | 3.00 | 30.24 | 4.09 |
| | Max. | | 9.24 | 90.76 | 6.14 | 28.50 | 9.80 | 44.91 | 7.28 | 4.56 | 2.44 | 1.66 | 67.16 | 1.55 | 23.54 | 4.03 | 33.95 | 5.98 |
| Medium protein grain mixture | Ave. | 27 | 11.02 | 88.98 | 5.27 | 19.87 | 8.95 | 49.95 | 4.93 | 3.18 | 2.05 | 1.23 | 64.01 | 1.45 | 15.77 | 3.59 | 37.87 | 3.75 |
| | Min. | | 13.27 | 86.73 | 4.74 | 18.69 | 7.71 | 47.39 | 4.00 | 2.99 | 1.88 | 0.95 | 62.62 | 1.31 | 14.88 | 3.11 | 36.06 | 3.06 |
| | Max. | | 9.47 | 90.53 | 5.86 | 21.13 | 10.34 | 51.58 | 5.73 | 3.38 | 2.58 | 1.71 | 65.36 | 1.62 | 16.82 | 4.17 | 39.25 | 4.19 |

AVERAGE, MINIMUM AND MAXIMUM ANALYSES—ROUGHAGES AND CONCENTRATES—continued

| | | | Chemical composition | | | | | | | | | | Digestible nutrients | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of analyses | Water | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract | Nitrogen | Phosphoric acid | Potash | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract |
| | | | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % |
| Low protein grain mixture | Ave. | 27 | 11.56 | 88.44 | 4.60 | 13.20 | 7.72 | 57.80 | 5.12 | 2.11 | 1.84 | 1.03 | 63.41 | 1.31 | 9.76 | 2.35 | 44.85 | 3.94 |
| | Min. | | 12.85 | 87.15 | 4.06 | 12.31 | 6.29 | 55.84 | 4.40 | 1.97 | 1.52 | 0.84 | 62.53 | 1.15 | 9.10 | 2.72 | 43.33 | 3.07 |
| | Max. | | 10.22 | 89.78 | 5.20 | 14.44 | 9.39 | 59.63 | 5.93 | 2.31 | 2.09 | 1.22 | 64.40 | 1.46 | 10.67 | 4.07 | 46.27 | 4.57 |
| Very low protein grain mixture | Ave. | 10 | 12.85 | 87.15 | 2.99 | 10.14 | 6.68 | 63.41 | 3.93 | 1.62 | 1.10 | 0.65 | 66.06 | 0.99 | 6.36 | 2.97 | 52.82 | 3.21 |
| | Min. | | 13.52 | 86.48 | 2.84 | 9.63 | 5.84 | 59.78 | 3.20 | 1.54 | 1.00 | 0.55 | 63.58 | 0.93 | 6.04 | 2.60 | 49.80 | 2.61 |
| | Max. | | 10.37 | 89.63 | 3.22 | 10.50 | 7.67 | 64.46 | 4.63 | 1.68 | 1.17 | 0.81 | 67.95 | 1.06 | 6.67 | 3.41 | 53.69 | 3.78 |
| Cottonseed meal | Ave. | 27 | 8.67 | 91.33 | 6.45 | 38.89 | 9.05 | 29.17 | 7.76 | 6.22 | 2.57 | 1.74 | | | | | | |
| | Min. | | 7.30 | 89.51 | 5.85 | 33.48 | 7.09 | 26.16 | 6.16 | 5.36 | 2.07 | 1.53 | | | | | | |
| | Max. | | 10.49 | 82.70 | 7.13 | 42.81 | 11.65 | 33.81 | 9.00 | 6.85 | 3.10 | 2.03 | | | | | | |
| Linseed meal | Ave. | 27 | 9.96 | 90.04 | 5.64 | 34.10 | 7.29 | 36.81 | 6.20 | 5.46 | 1.81 | 1.22 | | | | | | |
| | Min. | | 8.84 | 88.97 | 4.92 | 31.30 | 5.65 | 31.77 | 3.54 | 5.01 | 1.42 | 0.82 | | | | | | |
| | Max. | | 11.03 | 91.16 | 6.69 | 38.81 | 8.58 | 41.98 | 8.48 | 6.21 | 2.17 | 1.80 | | | | | | |
| Gluten feed | Ave. | 27 | 10.39 | 89.61 | 3.34 | 25.41 | 6.33 | 51.60 | 2.92 | 4.07 | 1.24 | 0.72 | | | | | | |
| | Min. | | 7.61 | 87.09 | 1.79 | 22.94 | 4.96 | 47.09 | 1.46 | 3.67 | 0.64 | 0.20 | | | | | | |
| | Max. | | 12.91 | 92.39 | 5.41 | 27.63 | 7.94 | 55.30 | 4.30 | 4.43 | 2.17 | 1.22 | | | | | | |
| Wheat bran | Ave. | 27 | 11.80 | 88.20 | 6.38 | 15.11 | 9.14 | 52.88 | 4.68 | 2.42 | 2.82 | 1.59 | | | | | | |
| | Min. | | 10.23 | 87.13 | 5.38 | 14.00 | 7.80 | 51.14 | 3.77 | 2.24 | 2.38 | 1.12 | | | | | | |
| | Max. | | 12.87 | 89.77 | 7.15 | 16.09 | 10.47 | 56.36 | 5.55 | 2.57 | 3.35 | 1.84 | | | | | | |
| Hominy feed | Ave. | 27 | 10.60 | 89.40 | 2.90 | 10.71 | 3.93 | 64.63 | 7.23 | 1.71 | 1.23 | 0.65 | | | | | | |
| | Min. | | 7.83 | 86.62 | 2.35 | 9.50 | 2.28 | 60.64 | 5.38 | 1.52 | 0.80 | 0.41 | | | | | | |
| | Max. | | 13.38 | 92.17 | 3.38 | 11.58 | 4.89 | 66.57 | 9.18 | 1.85 | 1.53 | 0.94 | | | | | | |
| Ground oats | Ave. | 27 | 11.99 | 88.01 | 3.54 | 11.40 | 9.24 | 59.80 | 4.04 | 1.82 | 1.11 | 0.56 | | | | | | |
| | Min. | | 9.35 | 86.14 | 3.01 | 10.25 | 6.98 | 55.34 | 3.08 | 1.64 | 0.64 | 0.39 | | | | | | |
| | Max. | | 13.86 | 90.65 | 4.83 | 13.33 | 12.28 | 62.11 | 5.41 | 2.13 | 1.02 | 0.84 | | | | | | |
| Corn and cob meal | Ave. | 10 | 14.81 | 85.19 | 1.86 | 7.89 | 6.03 | 66.81 | 2.60 | 1.26 | 0.54 | 0.39 | | | | | | |
| | Min. | | 10.42 | 73.94 | 1.44 | 6.77 | 3.70 | 55.12 | 1.29 | 1.08 | 0.35 | 0.27 | | | | | | |
| | Max. | | 26.06 | 89.58 | 2.30 | 8.81 | 7.70 | 70.43 | 3.59 | 1.41 | 0.80 | 0.49 | | | | | | |

The essential accuracy of the concentrate mixing processes at the barn, of the samples of mixtures and constituents and of analytical processes is attested by the following table, which compares the actual average analyses of the four mixtures with the calculated average analyses as determined by the analyses of the several constituents. It will be observed that the percentage differences are not large.

| | | Water | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract | Nitrogen | Phosphoric acid | Potash |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % | % | % | % |
| **Very low** | **Mixture** ....... | **87.15** | **2.99** | **10.14** | **6.68** | **63.41** | **3.93** | **1.62** | **1.10** | **0.65** |
| | **Calculation** .... | **86.85** | **3.07** | **10.15** | **6.73** | **62.95** | **3.96** | **1.62** | **1.13** | **0.66** |
| | **Calc. ± mix**.... | **—0.30** | **+0.08** | **+0.01** | **+0.05** | **—0.46** | **+0.03** | **0** | **+0.03** | **+0.01** |
| | **Calc. ± mix. %**. | **—0.3** | **+2.7** | **+0.1** | **+0.8** | **—0.7** | **+0.8** | **0** | **+2.7** | **+1.6** |
| **Low** | **Mixture** ....... | **88.44** | **4.60** | **13.20** | **7.72** | **57.80** | **5.12** | **2.11** | **1.84** | **1.03** |
| | **Calculation** .... | **88.48** | **4.58** | **12.79** | **7.68** | **58.21** | **5.23** | **2.05** | **1.88** | **1.03** |
| | **Calc. ± mix**.... | **+0.04** | **—0.02** | **—0.41** | **—0.04** | **+0.41** | **+0.12** | **—0.06** | **+0.04** | **0** |
| | **Calc. ± mix. %**. | **0** | **—0.4** | **—3.1** | **—0.5** | **+0.7** | **+2.4** | **—2.8** | **+2.2** | **0** |
| **Medium** | **Mixture** ....... | **88.98** | **5.27** | **19.87** | **8.95** | **49.95** | **4.93** | **3.18** | **2.05** | **1.23** |
| | **Calculation** .... | **88.91** | **5.25** | **19.90** | **8.75** | **50.19** | **4.82** | **3.18** | **2.12** | **1.24** |
| | **Calc. ± mix**.... | **—0.07** | **—0.02** | **+0.03** | **—0.20** | **+0.24** | **—0.11** | **0** | **+0.07** | **+0.01** |
| | **Calc. ± mix. %**. | **—0.1** | **—0.4** | **+0.2** | **—2.2** | **+0.5** | **—2.2** | **0** | **+3.4** | **+0.8** |
| **High** | **Mixture** ....... | **89.43** | **5.73** | **26.47** | **8.91** | **42.37** | **5.95** | **4.24** | **2.13** | **1.37** |
| | **Calculation** .... | **89.58** | **5.78** | **26.80** | **8.60** | **42.50** | **5.90** | **4.29** | **2.20** | **1.38** |
| | **Calc. ± mix**.... | **+0.15** | **+0.05** | **+0.33** | **—0.31** | **+0.13** | **—0.05** | **+0.05** | **+0.07** | **+0.01** |
| | **Calc. ± mix. %**. | **+0.2** | **+0.9** | **+1.3** | **—3.5** | **+0.3** | **—0.8** | **+1.2** | **+3.3** | **+0.7** |

## Scope of the Trials

It is easy to see that the feeding of so large a herd of cows for so long a time involved a vast amount of work. More than 300,000 milk weights were made; more than a 1,000,000 weights of fodders and feeds were made; many tens of thousands of milk samples were taken; many thousands were analyzed; several thousands of dry matter determinations and several hundreds of complete analyses of roughages and concentrates were made; and, finally, a stupendous amount of computation was necessary. The fact that in the summer of 1913, when the trials had been in progress eight years and had still six years to go, *the mere paper and ink of the records and computations weighed 301 pounds,* is indicative of the volume of the work.

## The Live Weights

The cows in the long continuous and the lactation alternation groups were weighed on three consecutive days every four weeks; those in the short alternation groups for three consecutive days at the beginning and at the close of the experimental portion of each feeding period; and at other times during experimental periods together with the main herd. The live weights of the cows fed in the short alternation trials are not printed. Half of the cows were young animals, increasing in weight regardless of ration changes; and a study of the weights of the more mature cows led almost nowheres—as is set forth on page 105. Hence their omission. The average weights for each lactation of the cows in the long continued trials are tabulated on pages 101 to 103 in connection with their discussion.

## CONCERNING THE WEATHER

Mark Twain once said: "We all talk about the weather—but nothing is done." Something was done in the present instance; not to control—would that we could—but to take cognizance of the thermometric changes.

It goes without saying that in a trial lasting twelve and one-half years the experimental animals were subjected to winter's cold and summer's heat; that sometimes the barn temperature went below 40° F.—but never to 32° F., although it came perilously near it in the bitter 1917-18 season—and that mid-summer heat was at times excessive. Whatever effect these thermometric deviations may have had, and unquestionably they exerted some temporary effects, it may be assumed safely that the ultimate accuracy of the outcome of these experimental trials was not imperilled. Obviously all the cows were similarly exposed to the vagaries of the weather, and at all times and in all the various forms of the trial the several experimental rations were being fed. And then again the very length of the trial serves to nullify the effects of weather changes.

Temperature records were taken thrice daily at 6 a. m., 12 m. and 6 p. m. in the main and the annex portions of the barn while the cows lived indoors. A careful study of these records leads the writers to conclude that their effect was nil and that their inclusion in the printed record would serve no good purpose. It may be further said that in the long series of feeding trials made at this Station from 1895 to 1905 and discussed in the several annual reports of those years, at no time did winter temperature changes serve materially to affect the outcome. Then, furthermore, in 1891, 1892 and 1893, thorough studies were made of the effect of weather on the milk flow.[1] The most extreme statement made in connection with the eleven winter seasons' trials appears in the seventeenth report, page 465, to the effect that the winter was a bitterly cold one; that barn temperatures often dropped below 40° F.; that there were four cold spells of several days' duration, during which barn temperatures averaged from 3° to 6° F. below normal; and that during these times the milk yields shrank from 0.4 to 0.7 pounds daily, or from 2½ to 4 percent, a shrinkage which seemed to bear no relation to the nature of the ration fed but to be fairly uniform and, presumably, a temperature effect. The tests reported from 1891 to 1893 were made under varying circumstances, with a large number of herds in May, June and July, with the station herd from mid-summer to late fall, and in late winter in a poorly constructed barn located on a bleak hillside. They covered conditions of pasture, summer soiling and winter feeding. They indicated clearly that from day to day cows tend to give somewhat richer milk when the temperature falls and somewhat poorer milk as it rises, that, in other words, milk tends to vary in richness in the inverse direction to temperature changes. These effects are temporary only; and since there are plenty of downs as well as ups, the ultimate result cannot have been materially affected.

And so it is with storm effects, which temporarily may be manifest but do not affect the ultimate outcome.

## II. THE COMPUTATIONAL METHODS

"The proof of the pudding is the eating thereof"; and the questions which were asked in 1906 were best answered by protein eating and milk making. In view of the fact that cows cannot talk, recourse must be had to performance records, which procedure, however, is not amiss when we recollect that "actions speak louder than words." But when one endeavors to interpret these performance records, to discover what their actions portray, he knits his brows; for while the verity of the two aphorisms already cited in this paragraph may be affirmed, the entire truth of the statement that "figures don't lie" seems open to question. Much depends upon methods of calculation and of presentation of data. White may be made to appear black by specious reasoning.

Hence it was that, in order to make the outcome as nearly certain as practicable, three parallel lines of experimental feeding practice were inaugurated in 1906, as is set forth in full on pages 14-15, viz.:

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[1] Vt. Sta. Rpt. 5, pp. 65-69 (1891); 6, pp. 128-135 (1892); 7, pp. 89-91 (1893).

1. Long continuous feeding, year in and year out with single rations, the same cows being used in identical rations.
2. Lactation alternation feeding, wherein cows were fed throughout an entire lactation on a definite ration, and throughout the next entire lactation on a different ration, and then throughout the next entire lactation again upon the definite ration first fed and soon.
3. Short alternation feeding, wherein cows were fed during five-week periods alternately on one or the other ration.

And hence it was that, in the final summations of the outcomes in 1915, and again in 1917 and in 1920-21, in order to make it as nearly certain and beyond criticism as possible, the data were worked over from several different standpoints. Thus, for example, the results secured by the three lines of feeding practice were independently calculated as follows in several different ways as is set forth at length on the following pages.

## THE FEEDING RECORD

The records were totalled for the long continuous cows and for the lactation alternation cows by lactation periods rather than by calendar years. They include only the time when the cows were actually in milk. Whenever abortion or other abnormality in freshening occurred, the record, though determined, has been excluded.

The records of the food consumed by the cows in the several long continuous and lactation alternation sub-groups are necessarily incomplete because the cows grazed during each summer. This situation was the subject of careful consideration at the time when the trials were originally formulated. However, the cows had to be turned out to pasture for the reason that the available tillable area on the University Farm is insufficient to provide roughage enough to carry the herd during the entire year. However, it should be clearly understood that the pasture was poor, was vastly overstocked and really, except in June and perhaps half of July, furnished a comparatively small proportion of the total food eaten. It may be urged in criticism that the cows on the low oı very low protein rations, eating perhaps a large amount of grass on pasture, might partially recuperate from the effects of an insufficient protein supply during the rest of the year. Such a stricture may be warranted to a limited extent; but since the pasture was poor both in quality and quantity, and had to be supplemented each summer with hay, silage, or soiling crops, exact weights of which were recorded, it is not thought that this undesirable but necessary occurrence vitally affected the results or impaired the outcome. The cows fed the low protein ration ate in their grain feed about 300 pounds less digestible protein during the course of a year than did those on the high protein ration. This shortage was located entirely in the concentrate part of the ration, since the roughage consumptions were essentially identical. A cow in the low protein group would have to consume six tons of grass in excess of that eaten by a cow in the high protein group in order to be on a par with the latter in respect to her protein intake. That would be equivalent to eating a hundred pounds of grass daily during June, July, August and September, over and above what the high protein group cow ate. In view of the fact that the cows fed medium and high protein rations were not idle while in the pasture, that, as has been stated, the pasture was scanty and greatly overstocked, and that for much of the season it was really hardly more than an exercising ground, and, finally, in view of the fact that the grain ration of all cows was cut in half from the time when they were turned out until mid-July, when pastures had become short and dry, the writers do not feel that this admittedly unfortunate break in the feeding procedure necessarily or probably had any material effect upon the ultimate outcome. However, on this account all the data have been calculated separately on the basis of the entire lactation including the summer feeding, and on the basis of the barn feedings only. While the former data, which include the summer pasture season, do not state specifically the units of food required to produce a unit of product, for the reason that the nutrients obtained in the pasture grass are not known and are consequently omitted, yet, notwithstanding, an excellent comparison is afforded, since the pasture days for each group are almost exactly the same, and the yields of milk and of each of the several solids, fat, casein and albumin, milk sugar and ash, are given in exact terms for the entire lactation period.

Considerable discussion was held between some of the writers as to the possibility of estimating the food intake in the pasture but no satisfactory method could be devised whereby this could be done.

Exact records were kept of all feed consumed and all products yielded by each cow during the winter feeding season, which was 175 days in length during the first winter and 210 days long during each of the ten succeeding winters. Owing to their exact nature these data may be used to determine without question the amount of food required to secure a unit of product from the very low, low, medium and high protein groups of cows respectively, and to check the results secured when the complete lactation periods including pasturage were used.

The short alternation feeding periods were five weeks long, the first two weeks being considered the preliminary and the last three the experimental portion. During the preliminary portion of the period, the data for which were not used in drawing conclusions but simply placed on file as a matter of record, the cows were enabled to become sufficiently accustomed to the changed ration so that—assuming the validity of the method of measurement—strict comparisons might be drawn safely from the data secured during the last three weeks of the feeding period. These same five-week divisions, consisting of two-week and three-week portions, were also made in recording the data for the long continuous and lactation alternation cows during the winter feeding season, in order to serve as a check upon the work of the short alternation cows.

The study of biometrics as applied to experimentation with dairy cows has been developed within the past ten years. These trials were under way and vast amounts of data accumulatd and calculated before this method had come to the front. After careful consideration of the whole proposition, it seemed best not to change the system of statement determined upon at the outset, realizing at the same time that the statistical method of statement is to be preferred.

### CONCERNING THE METHODS EMPLOYED IN COMPUTATION

In order beyond peradventure to be certain that pasture season influences did not affect the outcome, all data were independently calculated for the entire lactation period including the pasture season, and, also, for the 210 days (175 days in 1906-07) of the winter feeding season. The final computations, furthermore, were made in 12 different ways, the same data being calculated in these 12 ways, each of them apparently entirely legitimate, in order as nearly as practicable to be certain that by no chance might the ultimate outcome be affected by the manner of computation. For purposes of identification these will be denominated by letter and number, not only in the following explanatory statement, but also at the extreme left of each of the great tables A to F, inclusive, which are folded in opposite page 64. A 1 (L. C.), A 1 (L. A.), A 2 (L. C.), A 2 (L. A.), A 3 (L. A.); B 1 (L. C.), B 1 (L. A.), B 2 (L. C.), B 2 (L. A.), B 3 (L. A.); C 1 (L. C.), C 1 (L. A.), C 2 (L. C.), C 2 (L. A.), C 3 (L. A.); D 1 (L. C.), D 1 (L. A.), D 2 (L. C.), D 2 (L. A.), D 3 (L. A.); and the data in tables E and F are similarly identified. These letters and figures refer as follows: A to F, to the tables A to F, inclusive, folded in opposite page 64; L. C. to the long continuous feeding trials, for the description of the plan of which see page 14; L. A., to the lactation alternation feeding trials, for the explanation of the plan of which see page 14; 1, 2, 3, to the several methods of computation as expressed in the immediate context.

A. *Complete lactations;* each record is calculated for a complete lactation directly from total records.

B. *Winter feeding periods;* each record is calculated for 210 days (175 days in 1906-07) directly from total records.

C. *Complete lactations;* each record is calculated to the daily average basis by dividing the data by the number of days—be they more or less—actually used in each lactation period.

D. *Winter feeding periods;* each record is calculated to the daily average basis by dividing by 210 days (175 days in 1906-07).

E. *Complete lactations;* each record is calculated for a complete lactation directly from total records.

F. *Winter feeding periods;* each record is calculated for 210 days directly from total records.

After the data were assembled in the four ways designated above as A, B, C and D, then the three methods of computation designated as 1, 2 and 3 were followed. The numbered methods, 1, 2 and 3, were identical whether used in connection with A, B, C or D. The numbered methods, 1, 2 and 3, are applicable to the records made by the cows in the lactation alternation (L. A.); methods 1 and 2 to those of the cows in the long continuous (L. C.) groups.

1. The daily averages were computed directly from the totals of all the records on a given ration; that is to say, all the records made on a given ration having been segregated, the data were added and the sum divided by the total number of days.

2. The daily averages of the total of each cow's records on a given ration were obtained. The sum of these, if they pertain to the long continuous groups, divided by the number of cows in the group, gave the average desired. If they pertain to the lactation alternation groups, the sum of the daily average of the total of each cow's records on a given ration in any one group, divided by the number of cows in that group, gave the average for that group. Combining the three groups, the final averages on low, medium and high protein rations were found. There are three groups of cows in the lactation alternation groups, according as they are fed rations high and low, high and medium, or medium and low in their protein contents.

3. The daily average was computed from the totals of the records by first adding and averaging separately the records of the cows getting low and medium, low and high, or medium and high rations as determined by their protein contents, then combining these groups for the final averages on the high, medium or low protein rations respectively.

Illustration will doubtless tend to make more clear these several methods of calculation. The examples chosen for purposes of illustration might have been made to cover the entire 57 varieties of items which go to make up the summation of the work as shown in the great tables folded in opposite page 64; but so extensive a showing would simply make for confusion. Hence only two main items, total dry matter and milk yield, are used. Examples are given as applied to tables A and C and methods 1, 2 and 3 (L. A.) only, since the methods of procedure used in the formulation of tables B and D resemble those employed respectively in the construction of tables A and C save that only winter feeding periods of 210 days are concerned instead of entire lactation periods. In other words, the same data could be worked up, by way of example, in the six other ways, B 1, D 1, B 2, D 2 and B 3, D 3, but the method of calculation would be exactly the same as those given, save that all records would be for 210 days instead of for a full lactation.

It should be observed that identical data are used in the six examples hereinafter set forth. It should further be observed that the final figures obtained by the use of these different methods differ somewhat one as compared with another. It is on this very account, that identical data diversely manipulated do afford somewhat different results, that all 12 methods were used on all the data, a stupendous task, in order that no loophole should be left, so that there would seem to be no just reason for claiming that the interpretation of a given result was unwarranted on the ground that it was based upon a defective method of computation.

A 1 (complete lactation) and B 1 (winter feeding periods). Daily averages computed directly from totals; that is to say, the entire consumption and production figures on a given ration for a given number of lactations (A), or winter feeding periods (B), are added, and the summation divided by the total number of days during which all the cows were kept under the conditions of the feeding trials.

LOW PROTEIN

| Name of cow | Days in milk | Dry matter lbs. | Milk lbs. |
|---|---|---|---|
| Vie | 399 | 7,525.37 | 6,146.6 |
| " | 238 | 6,144.55 | 5,400.5 |
| " | 315 | 5,578.91 | 4,636.1 |
| Lena | 266 | 4,514.36 | 4,221.6 |
| " | 504 | 9,666.35 | 8,795.8 |
| Theta | 378 | 5,817.28 | 6,026.5 |
| Zillah | 294 | 5,664.26 | 5,877.6 |
| " | 399 | 8,730.36 | 8,110.1 |
| " | 399 | 6,566.95 | 6,859.2 |
| " | 273 | 5,348.75 | 4,689.6 |
| Total | 3,465 | 65,557.14 | 60,763.6 |
| Daily average |  | 18.92 | 17.54 |

(65,557.14 ÷ 3,465 = 18.92; 60,763.6 ÷ 3,465 = 17.54.)

C 1 (complete lactations) and D 1 (winter feeding periods). Daily averages computed in the same way as in A 1 and B 1, save that each record, before method 1 is applied, is reduced to the daily basis. The daily average consumption and production figures for each cow on a given ration for each lactation (C), or winter feeding period (D), are added, and the result divided by the total number of daily average records

LOW PROTEIN

| Name of cow | Days in milk | Dry matter lbs. | Daily average lbs. | Milk lbs. | Daily average lbs. |
|---|---|---|---|---|---|
| Vie | 399 | 7,525.37 | 18.86 | 6,146.6 | 15.40 |
| " | 238 | 6,144.55 | 25.82 | 5,400.5 | 22.69 |
| " | 315 | 5,578.91 | 17.71 | 4,636.1 | 14.72 |
| Lena | 266 | 4,514.36 | 16.97 | 4,221.6 | 15.87 |
| " | 504 | 9,666.35 | 19.18 | 8,795.8 | 17.45 |
| Theta | 378 | 5,817.28 | 15.39 | 6,026.5 | 15.94 |
| Zillah | 294 | 5,664.26 | 19.27 | 5,877.6 | 19.99 |
| " | 399 | 8,730.36 | 21.88 | 8,110.1 | 20.33 |
| " | 399 | 6,566.95 | 16.46 | 6,859.2 | 17.19 |
| " | 273 | 5,348.75 | 19.59 | 4,689.6 | 17.18 |
| Total |  |  | 191.13 |  | 176.76 |
| Final daily average—10 records |  |  | 19.11 |  | 17.68 |

A 2 (complete lactations), B 2 (winter feeding periods). The daily average of consumption and production of each cow is determined by adding all the records made on a given ration and dividing by the total number of days of feeding. If a given cow, Vie for example, is fed two rations in alternate lactations, low and high protein for example, the records on each ration are segregated as in the first tabulation as shown below. But one daily average record—for example, Vie 20.22, 17.00—is secured for each cow on each ration, be it low, medium or high in its protein content, whether fed for four or more lactations or for one only. If fed for only one lactation, the daily average as computed for that one lactation is used—for example, Theta, 15.39, 15.94; if fed for four lactations, the totality is divided by the total number of days and the one record used—for example, Zillah, 19.27, 18.71. In a word, the cow and not the lactation is the unit. Then the daily cow averages on a given ration are added and the sum divided by the number of averages. In the case of the lactation alternation group, a record is made on two different rations by each group; thus, for example, the group of cows fed a low protein ration in comparison with a high protein ration and also the group of cows fed a low protein ration in comparison with a medium protein ration, contribute each a record on the low protein diet. These two group records added and divided by two, form the final summation

### EXAMPLE

| | Low protein | | | High protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Vie | 399 | 7,525.37 | 6,146.6 | ... | ....... | ....... |
| " | 238 | 6,144.55 | 5,400.5 | 448 | 9,707.38 | 10,222.1 |
| " | 315 | 5,578.91 | 4,636.1 | 364 | 5,595.87 | 6,096.6 |
| Total | 952 | 19,248.83 | 16,183.2 | 812 | 15,303.25 | 16,318.7 |
| Daily average. | | 20.22 | 17.00 | | 18.85 | 20.10 |

(19,248.83 ÷ 952 = 20.22; 16,183.2 ÷ 952 = 17.00.)

| | Low protein | | | High protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Lena | 266 | 4,514.36 | 4,221.6 | 294 | 5,101.21 | 6,560.6 |
| " | 504 | 9,666.35 | 8,795.8 | 308 | 6,168.79 | 6,400.8 |
| Total | 770 | 14,180.71 | 13,017.4 | 602 | 11,270.00 | 12,961.4 |
| Daily average. | | 18.42 | 16.90 | | 18.72 | 21.53 |

| | Low protein | | | Medium protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Theta | 378 | 5,817.28 | 6,026.5 | 301 | 5,123.48 | 5,550.4 |
| Total | 378 | 5,817.28 | 6,026.5 | 301 | 5,123.48 | 5,550.4 |
| Daily average. | | 15.39 | 15.94 | | 17.02 | 18.27 |

| | Low protein | | | Medium protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Zillah | 294 | 5,664.26 | 5,877.6 | ... | ....... | ....... |
| " | 399 | 8,730.36 | 8,110.1 | 259 | 4,520.34 | 5,854.3 |
| " | 399 | 6,566.95 | 6,859.2 | 294 | 5,374.61 | 6,904.7 |
| " | 273 | 5,348.75 | 4,689.6 | 308 | 5,653.61 | 6,294.1 |
| Total | 1,365 | 26,310.32 | 25,536.5 | 861 | 15,548.56 | 19,053.1 |
| Daily average.. | | 19.27 | 18.71 | | 18.06 | 22.13 |

| | Low protein (2 cows) | | | High protein (2 cows) | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Total (Vie and Lena) | 2 | 38.64 | 33.90 | 2 | 37.57 | 41.63 |
| Average | 1 | 19.32 | 16.95 | 1 | 18.79 | 20.82 |

| | Low protein (2 cows) | | | Medium protein (2 cows) | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Total (Theta and Zillah) | 2 | 34.66 | 34.65 | 2 | 35.08 | 40.40 |
| Average | 1 | 17.33 | 17.33 | 1 | 17.54 | 20.20 |
| Total; two low protein averages | | 36.35 | 34.28 | | | |
| Final daily low protein averages | | 18.33 | 17.14 | | | |

C 2 (complete lactation) and D 2 (winter feeding periods). This method resembles A 2 and B 2 in every respect except that before method 2 is applied, each record is put on the daily basis by dividing by the number of days in the lactation (C) or winter feeding period (D).

### EXAMPLE

| | | Low protein | | | High protein | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Vie | 1 | 18.86 | 15.40 | .. | .... | .... |
| “ | 1 | 25.82 | 22.69 | 1 | 21.67 | 22.82 |
| “ | 1 | 17.71 | 14.72 | 1 | 15.37 | 16.75 |
| Total | 3 | 62.39 | 52.81 | 2 | 37.04 | 39.57 |
| Average | (÷ 3) | 20.80 | 17.60 | (÷ 2) | 18.52 | 19.79 |

| | | Low protein | | | High protein | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Lena | 1 | 16.97 | 15.87 | 1 | 17.35 | 22.32 |
| “ | 1 | 19.18 | 17.45 | 1 | 20.03 | 20.78 |
| Total | 2 | 36.15 | 33.32 | 2 | 37.38 | 43.10 |
| Average | (÷ 2) | 18.08 | 16.66 | (÷ 2) | 18.69 | 21.55 |

| | | Low protein | | | Medium protein | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Theta | 1 | 15.39 | 15.94 | 1 | 17.02 | 18.44 |
| Total | 1 | 15.39 | 15.94 | 1 | 17.02 | 18.44 |
| Average | | 15.39 | 15.94 | | 17.02 | 18.44 |

| | | Low protein | | | Medium protein | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Zillah | 1 | 19.27 | 19.99 | .. | .... | .... |
| “ | 1 | 21.88 | 20.33 | 1 | 17.45 | 22.60 |
| “ | 1 | 16.46 | 17.19 | 1 | 18.28 | 23.49 |
| “ | 1 | 19.59 | 17.18 | 1 | 18.35 | 20.44 |
| Total | 4 | 77.20 | 74.69 | 3 | 54.08 | 66.53 |
| Average | (÷ 4) | 19.31 | 18.67 | (÷ 3) | 18.03 | 22.18 |

| | | Low protein (2 cows) | | | High protein (2 cows) | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Total (Vie and Lena) | 2 | 38.88 | 34.26 | 2 | 37.21 | 41.34 |
| Average | 1 | 19.44 | 17.13 | 1 | 18.61 | 20.67 |

| | | Low protein (2 cows) | | | Medium protein (2 cows) | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Total (Theta and Zillah) | 2 | 34.70 | 34.61 | 2 | 35.05 | 40.62 |
| Average | 1 | 17.35 | 17.31 | 1 | 17.53 | 20.31 |

| | Days | Dry matter lbs. | Milk lbs. |
|---|---|---|---|
| Total; two low protein averages | 2 | 36.79 | 34.44 |
| Final; daily low protein average. | 1 | 18.40 | 17.22 |

A 3 (complete lactation), B 3 (winter feeding periods). This method is the same as A 2 and B 2 in every respect, except that each lactation is treated as a unit instead of each cow being thus treated. It is stated on page —— in the discussion under A 2 and B 2 that "but one daily average record is secured for each cow on each ration, be it low, medium or high in its protein content, whether fed for four or more lactations or for one only. If fed for only one lactation, the daily average as computed for that one lactation is used; if fed for four lactations, the totality is divided by the total number of days and the one record used. In a word, the cow and not the lactation is the unit." The exact reverse holds in calculating the data under A 3 and B 3, in that the cow which furnishes four or more records is not put on a parity with the one which furnishes a single record, but has as many times as much weight in determining the outcome as she furnishes records.

| | Low protein | | | High protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Vie | 399 | 7,525.37 | 6,146.6 | ... | ....... | ....... |
| " | 238 | 6,144.55 | 5,400.5 | 448 | 9,707.38 | 10,222.1 |
| " | 315 | 5,578.91 | 4,636.1 | 364 | 5,595.87 | 6,096.6 |
| Lena | 266 | 4,514.36 | 4,221.6 | 294 | 5,101.21 | 6,560.6 |
| " | 504 | 9,666.35 | 8,795.8 | 308 | 6,168.79 | 6,400.8 |
| Total | 1,722 | 33,429.54 | 29,200.6 | 1,414 | 26,573.25 | 29,280.1 |
| Daily average. | | 19.41 | 16.96 | 1 | 18.79 | 20.71 |

| | Low protein | | | Medium protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Theta | 378 | 5,817.28 | 6,026.5 | 301 | 5,123.48 | 5,550.4 |
| Zillah | 294 | 5,664.26 | 5,877.6 | 259 | 4,520.34 | 5,854.3 |
| " | 399 | 8,730.36 | 8,110.1 | 294 | 5,374.61 | 6,904.7 |
| " | 399 | 6,566.95 | 6,859.2 | 308 | 5,653.61 | 6,294.1 |
| " | 273 | 5,348.75 | 4,689.6 | ... | ....... | ....... |
| Total | 1,743 | 32,127.60 | 31,563.0 | 1,162 | 20,672.04 | 24,603.5 |
| Daily average. | | 18.43 | 18.11 | 1 | 17.79 | 21.17 |
| Total of two low protein daily average | 2 | 37.84 | 35.07 | | | |

| | Days | Dry matter lbs. | Milk lbs. |
|---|---|---|---|
| Final low protein daily average | 1 | 18.92 | 17.54 |

C 3 (complete lactations), D 3 (winter feeding periods). This method resembles A 3 and B 3 in every particular except that before method 3 is applied each record is put on the daily basis by dividing by the number of days in the lactation (C) or winter feeding period (D).

| | Low protein | | | High protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Vie | 1 | 18.86 | 15.40 | .. | .... | .... |
| " | 1 | 25.82 | 22.69 | 1 | 21.67 | 22.82 |
| " | 1 | 17.71 | 14.72 | 1 | 15.37 | 16.75 |
| Lena | 1 | 16.97 | 15.87 | 1 | 17.35 | 22.32 |
| " | 1 | 19.18 | 17.45 | 1 | 20.03 | 20.78 |
| Total | 5 | 98.54 | 86.13 | 4 | 74.42 | 82.67 |
| Daily average ....(÷ | 5) | 19.71 | 17.23 | 1 | 18.61 | 20.67 |

| | Low protein | | | Medium protein | | |
|---|---|---|---|---|---|---|
| | Days | Dry matter lbs. | Milk lbs. | Days | Dry matter lbs. | Milk lbs. |
| Theta ........... | 1 | 15.39 | 15.94 | 1 | 17.02 | 18.44 |
| Zillah ........... | 1 | 19.27 | 19.99 | 1 | 17.45 | 22.60 |
| “ ........... | 1 | 21.88 | 20.33 | 1 | 18.28 | 23.49 |
| “ ........... | 1 | 16.46 | 17.19 | 1 | 18.35 | 20.44 |
| “ ........... | 1 | 19.59 | 17.18 | .. | .... | .... |
| Total ............ | 5 | 92.59 | 90.63 | 4 | 71.10 | 84.97 |
| Daily average....(÷ | 5) | 18.52 | 18.13 | 1 | 17.78 | 21.24 |

| | Days | Dry matter lbs. | Milk lbs. |
|---|---|---|---|
| Total: two low protein averages | 2 | 38.23 | 35.36 |
| Final: daily low protein average. | 1 | 19.12 | 17.68 |

### COMPARISON OF RESULTS SECURED BY THESE SEVERAL METHODS[1]

| | Dry matter lbs. | Milk lbs. |
|---|---|---|
| Method A 1 ................................ | 18.92 | 17.54 |
| “ C 1 ................................ | 19.11 | 17.68 |
| “ A 2 ................................ | 18.33 | 17.14 |
| “ C 2 ................................ | 18.40 | 17.22 |
| “ A 3 ................................ | 18.92 | 17.54 |
| “ C 3 ................................ | 19.12 | 17.68 |

It has been suggested that the yields of milk, total solids, fat, etc., given by each cow during each lactation, and the consumption of the several nutrients for each cow during each lactation and during each period among the short alternaters should be published. This would entail the printing of a vast deal of figures and, it is thought, to little purpose. Should anyone desire to translate the data in tables A to F, inclusive, into terms of consumption and production for a lactation, for a year or otherwise for the average cow in each group, it can be done, using the average lactation and dry period data in the table on page 60. Furthermore, the great mass of original data as well as the computation sheets are on file in a fire proof vault in Morrill Hall and will be kept intact, so that they can be referred to at any time in the future by any one who may desire to pursue any detail.

### Concerning “Starch Equivalents”

It should be remembered that these trials were begun in 1906 and that a large part of the data were gathered prior to 1915 and much collated prior to that date. The “therm” was not born in 1906. The methods of statement now quite generally accepted had not been formulated. Much thought was given after the trials had been under way for a few years as to what method of statement should be employed and touching the terms in which food usage should be expressed. Following conferences, correspondence and careful study, it was decided to use the norms then in vogue—and two of them long in vogue—namely, “total digestible nutrients,” “digestible protein” and “starch equivalents.” Of course today “true protein,” “therms,” “metabolizable energy,” “net energy,” etc., are rapidly—and most properly—coming to the front and seem likely to be the terms in which experimental results in animal feeding will be stated for many years to come. However, to have re-calculated and re-expressed the great mass of data involved either in the protein trials or in the maintenance trials (see bulletin 226), including literally millions of separate items, the mere paper and ink of the records of which some years ago weighed more than 300 pounds—would have been a stupendous task. Furthermore, it was not deemed to be necessary, particularly in view of the fact that Armsby and Fries[1] have recently stated that: "Aside from experimental errors, there is no difference in principle between the two sets of values (Kellner's starch values, net energy values) but merely a difference in the manner of expression." It may not be amiss to say that some years ago a similar statement was made privately to one of us (A. A. B.) by the senior of these two authors.

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[1] It should be noted that none of these figures will be found in tables A and C folded in opposite page. The records of only a few of the many cows whose data contribute to these great tables were used in this explanatory statement for purposes of illustration.

We hear less of "starch values" than we did ten years ago. The term and the method of calculation are passing from the stage. Their validity as a measure of food values is questioned, especially as it applies to dairy feeding. Since, however, they are used in this bulletin, it seems worth while briefly to discuss them.

On the basis of carefully controlled experimentation, Kellner[2] formulated feeding standards in terms of "starch values." These computed production values were recognized from the outset as of somewhat limited application because of the fact that the trials were confined to one class of animal, namely, the ox, and that only about a dozen feeds were tested. However, approximate starch values were determined by computation from a long list of feeding stuffs. According to this statement, 1 pound of digestible protein was held to possess 0.94 pounds of starch value; 1 pound of digestible nitrogen free extract and crude fiber, 1 pound; 1 pound fat in roughage, roots, etc., 1.61 pounds; in cereals, factory and mill byproducts, 2.12 pounds; and in oil-bearing seeds and oil meal, 2.14 pounds. It was found necessary to make deductions from these starch values of from 5 to 30 percent with mill and factory byproducts and from 50 to 70 percent with straws to arrive at true starch values.

The "starch value" system has had both advocates and detractors. Some of the most recent statements, pro and con, may be cited as follows:

Eckles[3] (1913) finds the values too low as applied to dairy cows. Hansson[4] (1913, 1914) agrees with Eckles, deeming the figures inexact in milk production, especially in respect to the protein conversion factor which he would make 1.43 instead of 0.94. Stutzer[5] (1914) states that for oxen and swine the values are accurate, but that with cows "there is difference of opinion as to what proportion of the starch value must be given in the form of digestible protein."

Wood and Yule[6] (1914) having made some 400 trials with oxen and sheep indicate their inapplicability in the latter stages of fattening or when feeding is very liberal.

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[1] Jour. Agr. Sci. 9. 2, pp. 182-187 (1919); Abstr. E. S. R. 43, pp. 372-373 (1920).

[2] Landw. Kal. (1909) I., pp. 103-109; Ernahr. Landw. Nutztiere, pp. 153-163 (1907).

[3] Mo. Sta. Rsch. Bul. 7. p. 133 (1913); Abstr. E. S. R. 30, pp. 773-774 (1914).

[4] Landtbr. Akad. Handl. och. Tidskr., 52, 8, pp. 633-647 (1913); Meddel. Centralanst. Försöksv. Jordbruksomrädet. 85, p. 17 (1913); Fühling's Landw. Ztg., 63, 2. pp. 41-53 (1914); Abstr. E. S. R. 31. p. 371 (1914).

[5] Internat. Inst. Agr., Mo. Bul. Agr. Intel. and Plt. Dis., 5, 3, pp. 155-158 (1914); Abstr. E. S. R. 31, p. 663 (1914).

[6] Jour. Agr. Sci. 6, 2, pp. 233-251 (1914); Abstr. E. S. R. 32, pp. 166-167 (1915).

Murray[7] (1915) bears testimony similar to that of Wood and Yule and suggests the use of formulas rather than of feeding standards—these to be stated in terms of total digestible nutrients, with varying protein ratios for maintenance, growth, work, fattening and milk production.

Halnan[8] (1915) upholds the Kellner point of view, fully developing and discussing the starch equivalent theory.

Sjollema[9] (1914) holds with Eckles, Wood and Yule, and Murray as to the inapplicability of starch values in the feeding of milch cows, believing that the amount of protein needed to make a pound of milk cannot be accurately stated, and provisionally suggesting maintenance and milk production rations expressed in terms of protein, carbohydrates and starch values.

However, Fingerling[10] (1915) dissents from these periods of view, contending that since milk production depends upon the non-nitrogenous nitrogen supply, as well as upon that of protein, and since the usage of the latter is bound to be variable, Kellner's estimates, even though they are predicated on body growth, are well suited for use in connection with milk production.

Halnan[11] (1918) in cooperation with Wood, issued from the Cambridge University press a brochure, entitled "Computations and Nutritive Values of Feeding Stuffs," which contains "maintenance and production starch equivalents," which Murray[12] characterizes as "in effect the discredited total digestible nutrients, and not starch equivalent at all."

Finally, from this side of the water, oil has been poured upon the English waters troubled by Wood and his associates and by Murray in the form of a paper by Armsby and Fries[13] written "to remove misapprehensions as to the relationship between starch values, carbohydrate equivalents ('total' nutrients), metabolizable energy, and net energy." They state that the Kellner starch values "seek to express in another form * * * precisely what we have expressed in our net energy values, viz., the extent to which the feed is able to diminish or prevent loss of stored energy from the body (submaintenance rations) or to bring about a storage of energy in new tissues (fattening, growth, etc.)."

The statement made by these authors cited at the beginning of this discussion, namely, that "there is no difference in principle between the two sets of values but merely a difference in the manner of expression" is significant in this connection.

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[7] Jour. Agr. Sci. 7, 2, pp. 154-162 (1915); Abstr. E. S. R. 33, p. 870 (1915).

[8] Jour. Agr. Sci. 7, 2, pp. 163-174 (1915); Abstr. E. S. R. 33, p. 870 (1915).

[9] Jour. Landw. 62, 4, pp. 345-375 (1914); Abstr. E. S. R. 33, p. 673 (1915).

[10] Fühling's Landw. Ztg., 63, 6, pp. 185-189 (1914); Abstr. E. S. R. 32, p. 368 (1915).

[11] Loc cit.

[12] Sci. Prog., 14, 54, pp. 319-326 (1919); Abstr. E. S. R. 43, p. 372 (1920).

[13] Loc cit.

# III. THE RELATIVE VALUES OF RATIONS CARRYING DIFFERENT DIGESTIBLE PROTEIN CONTENTS

## 1. DURING USAGE CONTINUED OVER A LONG PERIOD OF YEARS

### (*a*) UPON THE MILK FLOW

The dairy cow uses protein in part to maintain her bodily status. She uses it in part to construct the foetus, but not largely, as is shown at length in bulletin 226 and has been amply demonstrated elsewhere. She uses it in part in milk making. Perhaps she uses it to some extent as a stimulus to milk making. In other words, from the protein in the food she ingests she builds nitrogenous tissue or replaces the wastage incident to its usage, she builds foetal structure, she places casein and albumin in the milk and, perhaps as a result of a plentiful supply, is incited to make more milk. Now protein costs money and its overusage is to be decried. Enough is said to be as good as a feast. What is enough protein? How much can a cow use to advantage? How little can she get along with? What are the economic metes and bounds in protein usage in dairy feeding?

The direct object of this long continued trial, as is stated at the outset of the introduction to this bulletin (page 8), was "to determine the effect upon the milk flow wrought by the long continued use of rations carrying either very low, or relatively low, or medium, or high digestible protein contents." It has been heretofore pointed out how painstakingly the data contributing to the determination of the effect upon the milk flow of the use of these four rations have been accumulated, how vast is its volume, how extensive the computations. The final tables A to F which set forth the closely condensed results appear folded in opposite page 64. Detailed explanations as to their nature appear on pages 43-49. The data are reduced on the one cow-one day basis. There is also included in this connection table G which sets forth in still more condensed form the essential outcomes in as succinct a fashion as seems possible.

It goes without saying that it would be fatuous, as well as impossible, to print the appalling amount of data secured in these trials. As has been heretofore indicated the mere paper and ink of the records some years ago weighed more than 300 pounds. It has been digested into tabular form which is of itself extremely formidable but does not seem to lend itself to further simplification. However, the great mass of original data and computations is to be kept in a fire proof vault at this Station, segregated by itself, and at any time can be consulted by any one who may wish to make use of it.

### COMPARISONS OF LOW, MEDIUM AND HIGH PROTEIN RATIONS

It at once becomes evident on studying tables A to D that the differences in the results attained when these three rations were fed are not large. Table G (upper left hand section) contains 240 figures other than the norms (100[1]), only 13 of which (5.4%) are less than 90 and only 4 of which (1.7%) are less than 88. Furthermore, it is to be observed that the results afforded by the use of the same data diversely calculated are not identical, either in terms of figures or of the trend of figures. Thus in table G (upper left hand section) the outcome is as follows:

| | Long continuous trials | | Lactation alternation trials | |
|---|---|---|---|---|
| | Agreement | Non-agreement | Agreement | Non-agreement |
| Gross production ........... | 4 | 0 | 2 | 2 |
| Gross food consumption..... | 2 | 2 | 4 | 0 |
| Economy of food usage...... | 3 | 1 | 4 | 0 |
| Economy of available food usage ................. | 3 | 1 | 4 | 0 |
| Production per unit of starch equivalent ............. | 4 | 0 | 4 | 0 |
| Production per unit of starch equivalent less maintenance ................. | 3 | 1 | 4 | 0 |
| Totals ............. | 19 | 5 | 22 | 2 |

NOTE.—"Gross production" is set forth in tables A to F, inclusive (that is to say in the great tables folded in opposite page 64), in the perpendicular column headed "average daily milk yield" and the eight perpendicular columns headed "yield of milk nutrients"; "gross food consumption" in the nine perpendicular columns headed "average daily consumption digestible nutrients"; "economy of food usage" in the six perpendicular columns headed "starch equivalent utilized for; digestible protein utilized for; carbohydrates and (fat × 2¼) utilized for"; "economy of available food usage" in the three perpendicular columns headed "starch equivalent less maintenance utilized for milk; digestible protein less maintenance for milk; carbohydrates and (fat × 2¼) less maintenance utilized for milk"; "production per unit of starch equivalent" in the seven perpendicular columns headed "1,000 pounds starch equivalent in food yielded"; "production per unit of starch equivalent less maintenance" in the last seven perpendicular columns headed "1,000 pounds starch equivalent in food (less that required for maintenance) yielded."

It is to be expected that agreements would be closer in the instances where the lactation alternation system was employed than in those where the cows were fed continuously upon one ration, for the reason that in the one case the same individuals were used on both sides of the comparison, whereas in the other different individuals were used on the one than on the other side of the comparison.

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[1] In six cases 99½ or 99+.

The fact that discordancies existed, that divergencies in results were obtained when the identical data were calculated in different ways; the fact that the outcome varied somewhat according to whether one accepted the one or the other method of calculation; the fact that ration I might be considered, in a sense, the winner if one method of calculation was employed, whereas ration II might be preferred if another method was used; all these considerations led to the making of the final condensation of tables A to D, in the form of table G (upper half) and in the subjoined table, where the vast volume of figures was brought down to a small compass and a comparable basis and where all the various methods of calculation and of feeding stood upon a parity.

The ultimate outcome thus expressed indicates that the low, medium and high protein rations ranked in a general way about as follows, 100 representing optimums[1];

| | Long continuous feeding | | | | | |
|---|---|---|---|---|---|---|
| Gross production | High | 100[2] | low | 96.1 | medium | 91.8 |
| Gross food consumption | High | 100 | medium | 97 | low | 94.9 |
| Economy of food usage | Low | 100 | high | 98 | medium | 93.9 |
| Economy of available food usage | Medium | 100 | low | 100 | high | 92.6 |
| Production per unit of starch equivalent | Low | 100 | high | 98.4 | medium | 93.8 |
| Production per unit of starch equivalent less maintenance | Medium | 100 | low | 99.7 | high | 93.2 |
| | Lactation alternation feeding | | | | | |
| Gross production | High | 100 | medium | 96.3 | low | 94.6 |
| Gross food consumption | Low | 100 | high | 99.8 | medium | 97.9 |
| Economy of food usage | High | 100 | medium | 98.9 | low | 94.6 |
| Economy of available food usage | Medium | 100 | high | 97.8 | low | 94.1 |
| Production per unit of starch equivalent | High | 100 | medium | 98.5 | low | 94.8 |
| Production per unit of starch equivalent less maintenance | Medium | 100 | high | 98.1 | low | 94.4 |

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[1] See explanatory "note" in the text on page 53.

[2] This table does not "check" with table G (upper left hand section) in that all optimums have been raised to the 100 value and other figures raised proportionately. For example, the 100 against which this footnote is debited represents four 100s, one 99½ and one 98, averaging 99.7. This figure being raised 0.3 involves raising the other two figures accordingly. Furthermore, exact fractions, i. e., to 0.1% and not to 0.5% were used.

| | | | Both methods | | | |
|---|---|---|---|---|---|---|
| Gross production | High | 100 | low | 95.2 | medium | 94.6 |
| Gross food consumption | High | 100 | low | 98.1 | medium | 97.7 |
| Economy of food usage | High | 100 | medium | 97.7 | low | 97.6 |
| Economy of available food usage | Medium | 100 | low | 96.5 | high | 95.9 |
| Production per unit of starch equivalent | High | 100 | low | 97.5 | medium | 97.3 |
| Production per unit of starch equivalent less maintenance | Medium | 100 | low | 96.4 | high | 96.1 |

It seems quite clear when one studies these data:

1. *Gross production.* That the cows eating the high protein ration made the most product.

2. *Gross food consumption.* That the cows eating the high protein ration ate the most food.

3. *Economy of food usage.* That the cows eating the high protein ration made, on the whole, the most economical use of their food; that is to say, of the total food; but

4. *Economy of available food usage.* That the cows eating the high protein ration did not make the best and most economical usage of the available food they ate; that is to say, of the total food less that assumed to be needed for maintenance purposes; that in this respect the cows fed both the medium and the low protein rations outclassed them.

5. *Production per unit of starch equivalent.* That the cows eating the high protein ration made the most per unit of starch equivalent in their food; but

6. *Production per unit of available starch equivalent.* That the cows eating the high protein ration did not make the most milk and solids per unit of starch equivalent when maintenance needs were deducted; that is to say, they did not make the most per unit of available starch equivalent, the cows eating the medium protein ration decidedly and those eating the low protein ration slightly outclassing them in this respect.

The question naturally arises, why did the cows fed the medium protein ration forge ahead of those eating the high protein ration when their *available* food intake is considered? A study of the original tables shows clearly that this is a matter of their live weights; that the medium protein fed cows were decidedly heavier than were their competitors. The maintenance deduction is of course predicated upon live weights. Now the live weights as stated in the tables on pages 101-103 are shown in the following table. The three columns of figures to the left represent the actual average weights as shown in the tables. The three columns of figures at the right represent their translation into percentages, the weights of the cows fed the high protein ration being treated as 100. The different figures (i. e., 892, 934) for each table (i. e., A, B, C, D) represent the five diverse methods of calculation of the same data as set forth on pages 43-49.

| | Actual average weights | | | Relationships High = 100 | | |
|---|---|---|---|---|---|---|
| | Low | Medium | High | Low | Medium | High |
| | lbs. | lbs. | lbs. | % | % | % |
| A. Long continuous ....... | 892 | 979 | 916 | 97 | 107 | 100 |
| | 934 | 924 | 901 | 104 | 103 | 100 |
| Lactation alternation ...... | 884 | 885 | 888 | 100 | 100 | 100 |
| | 877 | 872 | 882 | 99 | 99 | 100 |
| | 885 | 884 | 886 | 100 | 100 | 100 |
| B. Long continuous ....... | 933 | 1049 | 943 | 99 | 111 | 100 |
| | 929 | 1004 | 936 | 99 | 107 | 100 |
| Lactation alternation ...... | 899 | 876 | 880 | 102 | 100 | 100 |
| | 909 | 893 | 864 | 105 | 103 | 100 |
| | 902 | 885 | 871 | 104 | 102 | 100 |
| C. Long continuous ....... | 890 | 966 | 913 | 97 | 106 | 100 |
| | 934 | 926 | 911 | 103 | 102 | 100 |
| Lactation alternation ...... | 886 | 883 | 888 | 100 | 100 | 100 |
| | 878 | 871 | 883 | 99 | 99 | 100 |
| | 887 | 883 | 886 | 100 | 100 | 100 |
| D. Long continuous ....... | 931 | 1046 | 943 | 99 | 111 | 100 |
| | 929 | 1009 | 936 | 99 | 108 | 100 |
| Lactation alternation ...... | 897 | 874 | 877 | 102 | 100 | 100 |
| | 908 | 893 | 863 | 105 | 104 | 100 |
| | 899 | 884 | 869 | 103 | 102 | 100 |
| *Averages* | | | | | | |
| Long continuous ........... | 922 | 988 | 925 | 99.6 | 106.9 | 100 |
| Lactation alternation ....... | 893 | 882 | 878 | 101.8 | 100.8 | 100 |
| Both methods .......... | 904 | 924 | 897 | 100.7 | 103.2 | 100 |

The cows fed the medium protein ration continuously for a long series of years averaged 65 pounds heavier than did those fed the low or the high protein rations. They were seven percent heavier than their competitors. Now, theoretically, maintenance needs are proportioned to live weight; practically, however, it does not always seem to work out that way; that is to say, in cases such as the one now under consideration, the fact that a cow weighs somewhat more does not always mean that an equivalent of food is needed for the maintenance of the body status for the last few pounds of extra weight. Or, to phrase this matter in still another way, while, theoretically, it requires $\frac{1}{18}$ more food to maintain a 950 lb. cow in body status than it does to maintain a 900 lb. cow in body status, one does not feel absolutely certain that this fraction of necessity is correct. At any rate, in these long continued trials, the prime reason why the cows fed the medium protein ration appear to have outclassed those fed the high protein ration in respect to the economy of available food usage and economy of production per unit of starch equivalent less maintenance, and in these two points only, seems to be because they weighed seven percent more than did their rivals.

However, it will not do to overstress this statement, for the reason that as a matter of fact the cows continuously fed the medium protein ration, as compared with those continuously fed the low protein ration, did no better either in respect to economy of usage of available food constituents (100: 100) or in production per unit of starch equivalent less maintenance (100: 99.7). Yet the average low protein and the average high protein group cows weighed almost exactly the same. This apparent advantage afforded to the medium protein ration may have been due to bovine idiosyncrasy; and it must be remembered in this connection that it is the animals fed continuously for a long series of years upon identical rations that are being considered and not those which were shifted back and forth from one ration to another, being fed one during one lactation and another during another lactation. However, whatever the explanation, it certainly seems anomalous—as is shown in the data in the upper third of the table on page 54 that the cows fed for a working lifetime on the medium protein ration which made the least gross production (91.8), which made the least economical usage of total food ingested (93.9) and which made the least production per unit of total starch equivalent ingested (93.8), should, because, forsooth, they averaged to weigh seven percent more than did their competitors, stand at the head of the line, in that they made the most economical usage of available food constituents (100) and the most per unit of starch equivalent less maintenance (100).

On the other hand, in the lactation alternation trials, under conditions wherein so far as might be bovine idiosyncrasies were eliminated, and certainly were less to be reckoned with than in the case of the cows fed continuously throughout their working lifetime upon a single ration, the medium protein ration likewise outranked the others on the basis of the economy of usage of available food nutrients and in respect to the production per unit of starch equivalent less maintenance; that is to say, in precisely the same items in respect to which it proved superior in the long continued feeding trials. However, the differences, expressed as percentages, in the lactation alternation trials were not as large as in the other instances, when the results obtained with the medium and the high protein rations are compared, being, in fact, very little beyond the permissible limit of experimental error (100:98). The low protein ration, however, proved to be distinctly inferior to the other two throughout these lactation alternation trials, the average figures (exclusive of gross food consumption) being high (99.2), medium (98.7), low (94.5).

Another and somewhat simpler method of statement—likewise a condensation of data in the great tables A to D—appears below.

| Protein ration | Average daily records for the entire year | | | | | | Average daily records during seven winter months | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live weight | Total digestible nutrients | Digestible protein | Milk | Total solids | Fat | Live weight | Total digestible nutrients | Digestible protein | Milk | Total solids | Fat |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Low | 894 | 11.8 | 1.26 | 17. | 2.41 | 0.84 | 914 | 14.1 | 1.47 | 16. | 2.26 | 0.78 |
| Medium | 906 | 11.7 | 1.64 | 16.4 | 2.38 | 0.85 | 941 | 14.1 | 1.91 | 15.8 | 2.24 | 0.78 |
| High | 896 | 12. | 2.09 | 17.4 | 2.47 | 0.86 | 898 | 14.6 | 2.41 | 17.1 | 2.44 | 0.84 |

As is pointed out on page 33 the original plan of the experiment in respect to concentrate usage contemplated the feeding of seven pounds of grain during the seven barn feeding months to such cows as made the average total solid production. When the trials started out in 1906 a considerable portion of the experimental cows were grade Holsteins. These, of course, were relatively heavy milkers. Their numbers were not added to as the years went on but the proportion of grade Jerseys was greatly increased. It was quite commonly held among good dairymen 15 years ago that if one fed a pound of grain to 3 to 3½ pounds of milk the ratio was about right; and a similar feeling prevails today, with a tendency towards broadening the ratio and of feeding a pound of grain to from 3½ to 4 pounds of milk. It seemed safe to assume at the outset of these trials that the average milk production would range between 20 and 25 pounds. This assumption, however, proved erroneous, partly because of the larger proportion of grade Jerseys actually introduced into the trial as time went on, partly because of failure to breed and consequently the occurrence of over-long average lactation periods. The average milk yield for the entire year approximated 17 pounds or hardly more than three-quarters of the amount that was anticipated.

The following statement indicates the number of pounds of milk per pound of concentrate fed on the average in these trials.

| | One pound concentrate per pounds milk | | | | |
|---|---|---|---|---|---|
| | Very low | Low | Low | Medium | High |
| For the year............. | 2.9 | 3. | 2.6 | 2.6 | 2.6 |
| For seven months........ | 2.5 | 2.6 | 2.2 | 2.2 | 2.3 |

Obviously, concentrate usage was somewhat over-liberal. The actual average consumptions for the four rations throughout the year and during barn feeding were:

| | Very low | Low | Low | Medium | High | Intended |
|---|---|---|---|---|---|---|
| Year ............ | 5.2 | 5.6 | 6.5 | 6.4 | 6.6 | 6.4 |
| Seven months .... | 7.1 | 7.4 | 7.2 | 7.2 | 7.3 | 7. |

It was found necessary to feed less than seven pounds of the very low protein concentrate ration to reduce it to so low a protein basis and the low protein concentrate ration was fed in similarly small quantities in comparison with its very low competitor in order more accurately to maintain the balance with the other rations in respect to the proportions of grain and roughage fed. However, during the barn feeding months the full seven pound ration was fed and the digestible protein intake was somewhat larger than had been contemplated.

Roughage was fed in ample, though not excessive, quantities. It is quite clear that the cows were maintained as a whole on a somewhat high nutritional plane. Their general tendency to maintain or to increase body weight is testimony in this direction. Whether the same results would have been attained had the cows been fed a diet more restricted in its total digestible nutrient intake is a moot question. The writer is of the opinion that the outcome would have been in the same general character; but this is only an opinion.

The question naturally arises whether the average lactations in the various groups and the average dry periods were essentially similar or were unlike. If unlike, conceivably this may have affected the outcome. The life histories in respect to successive calvings and dryings off (pages 19-22) enable one to make the following calculations which clearly indicate that this was not a vital factor in the result.

| | Long continuous feeding data | | | | | Lactation alternation feeding data | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of cows in group | Average number of lactations | Average length of lactation, days | Average length of period while dry, days | Average total length of lactation, including period while dry, days | Number of comparisons | Average length of lactation, days | Average length of period while dry, days | Average total length of lactation, including period while dry, days |
| Very low... | 7 | 3.4 | 326 | 63 | 389 | 13 | 337 | 47 | 384 |
| Low ....... | 8 | 6.9 | 370* | 66 | 436 | 52 | 345 | 56 | 401 |
| Low (excluding Aggie) | 7 | 7.3 | 337 | 66 | 403 | .. | ... | ... | ... |
| Medium .... | 12 | 4.1 | 325 | 69 | 394 | 38 | 361 | 53 | 414 |
| High ...... | 15 | 2.8 | 340 | 75 | 415 | 41 | 343 | 52 | 395 |
| | On percentage basis. Very low data = 100 | | | | | | | | |
| Very low... | .. | .. | 100 | 100 | 100 | .. | 100 | 100 | 100 |
| Low ....... | .. | .. | 113.5* | 104.8 | 112.1 | .. | 102.4 | 119.2 | 104.5 |
| Low (excluding Aggie) | .. | .. | 103.4 | 104.8 | 103.6 | .. | .... | .... | .... |
| Medium .... | .. | .. | 99.7 | 109.5 | 101.3 | .. | 107.1 | 112.8 | 107.8 |
| High ...... | .. | .. | 104.3 | 119. | 106.7 | .. | 101.8 | 110.6 | 102.8 |

There seems to be no reason to assume, in respect to the duration of the milking period or of that during which the cows remained dry, that material differences occurred as between the results secured when using the rations originally fed, that is to say, the low, medium and high protein rations. Averaging the percentage statements, we have the following showings:

| Actual lactation period | | | | Lactation period plus dry period | | | |
|---|---|---|---|---|---|---|---|
| Very low | Low | Medium | High | Very low | Low | Medium | High |
| 100 | 102.9 | 103.4 | 103.1 | 100 | 104.1 | 104.6 | 104.7 |

It would seem as if the cows fed the very low protein ration tended on the whole to go dry a bit quicker than did those fed the other rations and to freshen again a little sooner, but it hardly seems as if the difference was sufficient materially to affect results.

The average cow in each of the four groups as each trial began was approximately from 4¼ to 5⅙ years old and during mid-trial was was approximately from 6½ to 8 years old. It seems fair to assume that in this respect no one ration was materially advantaged as compared with its competitors.

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*This figure is abnormally high because the cow Aggie persistently failed to breed. Her lactations were respectively 20, 21, 21½ and 14½ months in duration, an average of 578 days. No such record occurs in the other groups, their high marks being 536 days (one lactation), 412 days (two lactations) and 423 days (two lactations). These four records constituted respectively 7.2, 2.3, 4.2 and 8.3 percents of the data of the four groups. Obviously, Aggie's idiosyncracy profoundly affects the average; hence the supplementary horizontal columns.

It has been suggested that possibly variation in the times in freshening might have affected results; that, for example, if an undue proportion of the cows fed the two low protein rations came in milk at any given time and particularly when about to go to pasture, i. e., April, May, June, July, it was conceivable that the outcome to some extent might have been affected by this fact. Consequently the following summation has been made with a view of determining this matter:

| | Records | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % | % | % | % | % | % | % |
| Low and very low | 154 | 15 | 9 | 5 | 9 | 6 | 8 | 7 | 7 | 10 | 8 | 6 | 9 |
| Medium .. | 96 | 9 | 6 | 4 | 13 | 6 | 4 | 7 | 10 | 11 | 11 | 7 | 9 |
| High .... | 94 | 14 | 7 | 4 | 6 | 6 | 7 | 5 | 13 | 9 | 12 | 10 | 6 |
| Total .... | 344 | 13 | 8 | 5 | 9 | 6 | 7 | 7 | 10 | 10 | 10 | 7 | 8 |

Segregating these data by three four-month periods, the winter months, December-March; spring and early summer months, April-July; late summer and fall months, August-November; we find that, in general terms, the results are as follows, stated in terms of fractions:

| | Winter | Spring-summer | Summer-fall |
|---|---|---|---|
| Low ration ........................ | 3-8 | 1-3 | 1-3 |
| Medium ration ................... | 1-4 | 1-3 | 3-8 |
| High ration ....................... | 1-3 | 1-4 | 3-7 |
| All rations ........................ | 1-3 | 3-10 | 3-8 |

Obviously, the differences are not large; for 33, 30 and 37 percents are all pretty much the same. Furthermore, the cows fed the low protein rations which would have been the ones, if any, which would have been affected by pasture feeding, so far as the outcome is concerned, were very evenly distributed among the three groups. It seems safe to assert that the distribution of the freshening periods as between the various times of year was as even as could be expected.

A study of the dates of drying off and calving indicates that in general terms the average duration of the dry period was a little over two months; some shorter, some much longer. It is obviously impossible to make as clearcut a presentation of the results as in the case of dates of calving, but in a general way the following table indicates the percentage statements as to the dry periods.

| | 1-3 | 2-4 | 3-5 | 4-6 | 5-7 | 6-8 | 7-9 | 8-10 | 9-11 | 10-12 | 11-1 | 12-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Two low rations | 9 | 7 | 12 | 7 | 6 | 8 | 7 | 5 | 8 | 12 | 7 | 12 |
| Medium ration.. | 6 | 4 | 10 | 6 | 7 | 4 | 20 | 11 | 7 | 7 | 14 | 4 |
| High ration.... | 6 | 6 | 3 | 5 | 6 | 5 | 20 | 8 | 5 | 11 | 14 | 11 |
| All rations..... | 8 | 6 | 9 | 6 | 6 | 6 | 14 | 8 | 7 | 10 | 11 | 9 |

NOTE.—1-3, 2-4, etc., means January-March, February-April, etc. The figures 9, 7, 12, etc., mean that the dry periods of 9%, 7%, 12% of the total number of cows (100%) were located as indicated.

Segregating in three groups, $\frac{11}{1}$-$\frac{2}{4}$ ; $\frac{3}{5}$-$\frac{6}{8}$ ; $\frac{7}{9}$-$\frac{10}{12}$, we have the following statement, expressed as fractions:

| | Winter | Spring-summer | Summer-fall |
|---|---|---|---|
| Two low rations .............. | 1-3 | 1-3 | 1-3 |
| Medium ration ............... | 1-4 | 1-4 | 1-2— |
| High ration ................. | 3-8 | 1-5 | 3-7 |
| All rations .................. | 1-3 | 1-4 | 2-5 |

There was a tendency, especially with the cows fed the medium and high rations, to run dry somewhat more often during the months of short pasture than at any other time of year. This would seem to indicate that, except for the month of June, the pasture was not a source of any material amount of food nutrients, since a much larger proportion of the total number of cows went dry in July than in any other month of the year, their grain being cut somewhat (see page 34), the pastùre from mid-July onward furnishing not a very large proportion of food (see page 41), soiling crops being fed as well as grain rations increased in late July (see page 26). Once more it can be said that apparently the pasture factor did not control.

The writer, as a result of protracted and most careful study of all the data from the very initial material through to the final computations—for which latter he alone is responsible—is forced to conclude that the results of these long continued trials do not emphasize the primacy of protein; that a ration containing approximately 2 pounds of digestible protein per 1,000 pounds of live weight, year in and year out, produced fully as much as did a ration containing approximately 2.5 pounds of digestible protein per 1,000 pounds of live weight, the total amount of digestible nutrients in each case being essentially identical; and that a ration containing 1.5 pounds of digestible protein per 1,000 pounds of live weight, year in and year out, produced about 95 percent as much as did rations containing from one-third to two-thirds again as much protein but otherwise essentially identical amounts of digestible nutrients. Of course one should not fail to take into account in this connection the relation of these several rations to the maintenance of live weight (see pages 100-101) and of physical well being (see pages 68-100).

### COMPARISONS OF VERY LOW AND LOW PROTEIN RATIONS

In 1914 the trials had been under way for seven years and the data in part computed. It was apparent that a 1,000 pound cow could get along on a 1.5 pounds daily digestible protein intake and live to tell the tale in the form of a reasonably good, although possibly not a large, milk flow. Hence it seemed advisable to lower the protein intake and try again; and for the next five years cows were fed in a competitive way on rations carrying approximately a 1.5 pounds daily digestible protein content and 1 pound daily digestible protein content per 1,000 pounds live weight. The later ration was known as the "very low" protein ration.

This portion of the trials was beset with troubles. No less than 26 lactation records for one reason and another were rendered useless. Eleven cases of abortion occurred; in three instances the cows gave so little milk and stripped for so long a time that the records were of little use;[1] in three cases sterility interfered; in two instances the cows came in too late and in two went dry too quickly to render the records of service; and five of the very best records in the entire trial were made of no avail because of an unfortunate oversight in the conduct of the feeding operations on the part of the animal husbandman then in charge of the trials. Hence it is that the records of this important part of the trial are much less satisfactory than could be wished. However, 32 lactations contributed to the final result, 19 being of cows fed the very low ration.

The outcome in respect to the very low ration as compared with the low ration is more pronounced than was the case with the low, medium and high protein rations; but the result seems distinctly less clearcut because of the multitudinous calamities above indicated and the relatively small amount of available data. Then, too, the results are not uniform. The trend is both this way and that, and, on the whole, if the figures do not lie, it would seem as if the very low ration was a little the better of the two. In the lactation alternation trials the very low protein ration proved superior in 38 percent and the low protein ration in 42 percent of the comparisons, the remainder being indeterminate. In the long continued trials, involving long continuous feedings for several successive lactations, the very low protein ration proved superior in 63 percent and the low protein ration in 37 percent of the comparisons.

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[1] The prolonged small milk flow is not to be ascribed to the use of the very low protein ration, for the reason that cows fed the low protein ration were also longtime strippers. Note in this connection the statement as to the average lactation lengths in the table on page 60.

Tables E to F tell the story; but they contain a multiplicity of figures. Hence there is offered the following condensed statement, which resembles the similar tabulation on pages 54-55.[1]

| | Long continuous feeding | | | |
|---|---|---|---|---|
| Gross production | Very low | 100 | Low | 97.7 |
| Gross food consumption | Low | 100 | Very low | 93.5 |
| Economy of food usage | Very low | 100 | Low | 89.8 |
| Economy of available food usage | Very low | 100 | Low | 92.9 |
| Production per unit of starch equivalent | Very low | 100 | Low | 90.7 |
| Production per unit of starch equivalent less maintenance | Very low | 100 | Low | 93.3 |

| | Lactation alternation feeding | | | |
|---|---|---|---|---|
| Gross production | Low | 100 | Very low | 96 |
| Gross food consumption | Low | 100 | Very low | 98.7 |
| Economy of food usage | Low | 100 | Very low | 96.8 |
| Economy of available food usage | Low | 100 | Very low | 98 |
| Production per unit of starch equivalent | Low | 100 | Very low | 97.3 |
| Production per unit of starch equivalent less maintenance | Low | 100 | Very low | 98.5 |

| | Both methods | | | |
|---|---|---|---|---|
| Gross production | Low | 100 | Very low | 99.3 |
| Gross food consumption | Low | 100 | Very low | 96.3 |
| Economy of food usage | Very low | 100 | Low | 97.5 |
| Economy of available food usage | Very low | 100 | Low | 97.4 |
| Production per unit of starch equivalent | Very low | 100 | Low | 96.7 |
| Production per unit of starch equivalent less maintenance | Very low | 100 | Low | 97.5 |

It seems quite clear:

(1) That, taken as a whole, the cows fed the very low protein ration made almost as much, if not quite as much, as did those fed the low protein ration.

2) That, taken as a whole, the cows fed the very low protein ration ate somewhat less heartily than did those fed the low protein ration, the average consumption shortage approximating 3½ percent.

(3) That since, taken as a whole, the cows fed the very low protein ration made as much as and ate less than those to which the low protein ration was fed, naturally and inevitably the former group made more economical use of total nutrients, of available nutrients and made more per unit of starch equivalent and per unit of starch equivalent less than needed for maintenance.

All of which, being interpreted, seems to mean that in these trials the very low protein ration, affording approximately one pound

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[1] See explanatory "note" in the text on page 53.

per day of digestible protein per 1,000 pounds live weight, proved almost if not quite as effective as a milk maker as did the low protein ration furnishing approximately 1.5 pounds digestible protein per day per 1,000 pounds live weight; and, furthermore, that this held true for a considerable series of years of continuous feeding.

Another method of statement, likwise a condensation of the data in the great tables E and F, appears below:

| Ration | Average daily records for the entire year | | | | | | Average daily records during seven winter months | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live weight | Total digestible nutrients | Digestible protein | Milk | Total solids | Fat | Live weight | Total digestible nutrients | Digestible protein | Milk | Total solids | Fat |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Very low | 831 | 9.35 | 0.75 | 14.9 | 2.21 | 0.79 | 837 | 13.6 | 1.08 | 17.6 | 2.62 | 0.91 |
| Low | 872 | 10.15 | 1.02 | 16.5 | 2.33 | 0.80 | 869 | 13.5 | 1.41 | 19. | 2.71 | 0.92 |

The results thus presented differ from those set forth above. The low and very low protein rations are to each other expressed as ratios as follows:

| | Year | Seven months | Year | Seven months | Year | Seven months |
|---|---|---|---|---|---|---|
| | Milk | | Total solids | | Fat | |
| Low ........... | 100 | 100 | 100 | 100 | 100 | 100 |
| Very low ...... | 90 | 93 | 94½ | 96½ | 99 | 99 |

The low protein ration was the better milk maker of the two, but the milk made thereon was of a somewhat lower quality. There was little to choose between the two rations in respect to their total solid returns (100:95½) and nothing in respect to their fat returns (100:99).

It may be true in practice that the very low protein ration will continually prove sufficient and satisfactory, if one thinks only of the immediate result and not of the possible untoward effect upon the animal. Consequently the question of the effect on the live weight and on the continued physical well-being of the cow should be borne in mind. Reference should be had to the discussion on pages 106 to 107 in respect to the effect of the very low protein ration to live weight, and on pages 81 to 106 in respect to its effect upon physical well-being.

Certain questions should be raised at this point. Were the cows fed a super-maintenance ration when dry, especially of digestible protein? If so, did they increase in live weight as a result and thus become the better prepared for possible under-nutrition during the succeeding lactation period? Furthermore, did the cows increase materially in weight while at pasture, whether dry or in milk; in the former case becoming thus the better prepared for possible subsequent under feeding?

1. *Concerning possible super-maintenance feeding while dry.* The length of the yardstick naturally affects the answer to the first question. Two unlike sets of figures are suggested in this connection 0.7 and 7.93 pounds, respectively, of digestible protein and digestible dry matter by Wolff-Lehmann, Haecker, Savage and many others; 0.5 pounds true protein and 6 therms of energy, equivalent to 0.595 and 6.48 pounds of digestible protein and digestible dry matter, respectively, (see bulletin 226) by Eckles and by Armsby. The ratios are 1 : 0.82 and 1 : 0.85. One must take both standards into account.

It is, of course, obvious that if the cows fed the high protein ration ate any material amount of grain while dry their digestible protein intake exceeded the higher standard figure. It is equally obvious, if the cows fed the very low protein ration—which theoretically furnished only a pound a day to the full milking 1,000-pound cow—ate no grain or even small quantities of grain when dry, that their digestible protein intake was not likely to exceed the higher standard figure. The cows fed the low and the medium protein rations might or might not consume, when dry, amounts of digestible protein in excess of maintenance needs. The situation is less obvious than in the other cases.

However, reference to the facts is to be preferred to speculation. The following statement sets forth the essential facts as to the nutrient consumption in 103 instances wherein the cows were dry for a period of eight or more weeks prior to parturition. Every such instance is included, except when abortion occurred.

It is to be remembered that these cows were almost invariably in the latter stages of pregnancy—although some of the dry periods were more than 16 weeks long. Cows in this condition, theoretically at any rate, need more than a mere maintenance ration at such a time, certainly in respect to its digestible protein content. Studies made here (bulletin 226, sections III, IV) and elsewhere indicate that during the

| Ration | Records | Average weeks fed while dry | Average daily digestible dry matter usage | Average daily digestible protein usage | Digestible dry matter below 7.93 | Digestible dry matter below 5.95 | Digestible protein below 0.7 | Digestible protein below 0.595 | Digestible protein below 0.81[1] | Digestible protein below 0.71[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | lbs. | lbs. | | | | | | |
| Low protein ....... | 36 | 13 | 9.92 | 0.86 | 3 | 0 | 8 | 2 | 15 | 8 |
| Medium protein .... | 18 | 13 | 9.49 | 0.76 | 2 | 0 | 4 | 1 | 7 | 5 |
| High protein ...... | 26 | 11 | 9.88 | 0.90 | 1 | 0 | 3 | 2 | 9 | 3 |
| Very low protein... | 23 | 13 | 9.16 | 0.68 | 2 | 0 | 12 | 7 | 19 | 12 |

[1] See text below.

last few months of pregnancy from 0.15 to 0.2 pounds of digestible protein are required over and above maintenance needs per 1,000 pounds of live weight. Assuming the mean figure, 0.175, and the average live weight at 900 pounds, a close approximation to the truth, the total figures for maintenance and foetal construction are 0.81 and 0.71 pounds respectively, which tally with reasonable closeness with the average figures in the above table.

It seems safe to assume that while several cows in each group, other than that fed the very low protein ration, were fed while dry on a somewhat overhigh nutritional plane, especially in respect to digestible dry matter, and occasionally in respect to digestible protein, on the average the cows eating the medium and very low protein rations were not overfed and those fed the low and high protein rations not materially overfed with digestible protein during the time when they were dry.

2. *Concerning possible weight increases while dry.* Speaking generally, the pregnant cows increased in live weight—and all these cows were pregnant. It does not appear, however, that the increment was materially greater than that of the uterine contents. No conscious attempt was made to fatten the cows at this time. Non-pregnant cows did not figure in this trial. Data concerning their live weights are shown in bulletin 226, dealing with maintenance trials.

3. *Concerning possible weight increases at pasture.* No evidence is in hand indicating any essential gain in live weight on the home pasture. Indeed, it would seem as if the tendency ought to have been in the opposite direction. The full milking habit of June, the short pasturage of July and August, the hot weather, the flies, all these would seem to induce loss rather than gain in live weight. The question has

not been studied with extreme care in this connection, but a somewhat extended survey of the records during several summers tends to bear out this statement. Furthermore, while barn fed, the three main groups on the average weighed, ate (except of digestible protein) and yielded much the same, average extremes being: live weight, 4 percent; hay, silage and grain usage, 3, 3 and 1 percents; dry matter usage, 1 percent; milk yield, 6 percent. Then again, the low protein fed cows as a class did not seem to lose weight (pages 100-105). The very low protein fed cows doubtless recouped somewhat at pasture (pages 105-107).

However, the situation was somewhat different with the cows likely to be dry for a considerable length of time. They were usually sent to a distant pasture of better grade than the home pasture which was not overstocked. It is quite possible that some of the cows on low or very low protein rations, due to calve from August to October, may thus have been somewhat advantaged.

### (*b*) UPON THE PHYSICAL CONDITION OF THE COWS

The cows used in these several trials so far as could be determined were in thoroughly good physical condition when they entered upon their labors. Obviously if any ration used tended to lower vitality, or otherwise to impair the usefulness of the cows, the fact should be debited against it. In other words, the continued well-being of the animals should be considered as well as the milk yields in the formation of judgment as to the value of any given ration. Consequently, several careful physical examinations were made by persons who might well be classed as expert bovine diagnosticians, in order to determine if possible whether or not any ill-effects were observable which justly might be ascribed to the nature of the feeding. Since the muscular tissues, hair, hide, the vital organs, etc., are constructed in large part of protein derived from the digestible protein of the food and since the amounts of digestible protein ingested by the various groups were widely unlike, it was perhaps not unreasonable to expect that noticeable differences might be observed, in view of the fact that experimental feeding had in some cases lasted from seven to ten years. Then, too, in the somewhat similar experiments carried on at Minnesota it is stated that such differences were detected, as is set forth on pages 174-177.

Five separate physical examinations were held, on July 8, 1913, September 21, 1914, May 19, 1916, May 24, 1917, and May 27, 1918, and, finally, in July 1919, superficial examinations were made by the station animal husbandman.

The persons who were chosen for this work—other than the station veterinarian and the several animal husbandmen—knew little or nothing about the cows further than that they had been under experiment involving special feeding practice for a considerable length of time. The names of the cows, their identities, the nature of the rations used were in all cases unknown to the examiners. Indeed, to several of the judges the very nature of the trials was unknown when they passed judgment. It was the common practice to place the cows in a single row, and they were numbered and known to the members of the judging board by number only. Furthermore, the cows from the several groups were intermingled. And, finally, the judges as a rule worked independently and without consultation with each other, except in the two cases cited in the discussion of the second examination. In every case the individual judge went at his problem pretty much after his own fashion, using his own methods, although they naturally collaborated more or less.

The personnel of the boards were:

1913. F. W. Chamberlain, D. V. S., Professor of Veterinary Anatomy (now Acting Dean of the Department of Veterinary Science), Michigan Agricultural College; F. A. Rich, V. S., M. D., Professor of Veterinary Science, University of Vermont, (then) Station Veterinarian; L. E. Brigham, long time cattle buyer, for many years in charge of the plant of the Burlington Rendering Company in this city; A. A. Borland, M. S., (then) Professor of Dairy and Animal Husbandry, University of Vermont, Station Animal Husbandman.

1914. F. A. Rich; G. W. Stockwell, breeder of Ayrshire cattle, in employ of Chapin & Co., feed manufacturers.

1916. F. A. Rich; J. A. McLean, B. S. (then) Professor of Animal Husbandry, Massachusetts Agricultural College, now with the Quaker Oats Co., Chicago, Ill.; G. W. Stockwell; G. F. E. Story, B. S. (then) Professor of Animal and Dairy Husbandry, University of Vermont, Station Animal Husbandman.

1917. P. A. Campbell, B. S. (then) manager of the Balsam Stock Farm, Dixville Notch, N. H., formerly Professor of Animal Husbandry, University of Maine, now manager of a farm in New Jersey; J. C. McNutt, B. S. (then) Professor of Animal Husbandry, Massachusetts Agricultural College, now Professor of Animal and Dairy Husbandry, New Hampshire; E. S. Savage, Ph. D., Professor of Animal Husbandry, Cornell University; and G. F. E. Story.

1918. J. C. McNutt, B. S.; F. A. Rich; H. B. Ellenberger, Ph. D., Professor of Animal and Dairy Husbandry, Station Animal Husbandman; G. F. E. Story (formerly Professor of Animal and Dairy Husbandry), General Manager Worcester County (Massachusetts) Farm Bureau; J. E. Carrigan, B. S., Assistant County Agent Leader, Vermont Extension Service.

The first two examinations conducted when the trials had been under way 6½ and nearly 8 years, had to do with the cows which had been fed low, medium and high protein rations; the last three dealt with a small number of animals fed either the low or the very low protein ration, as well as with some continued on the medium and high rations.

## THE 1913 EXAMINATION

Three groups of eight cows each were made in December, 1906, when the trials were inaugurated; and from that time onwards these cows were fed unchanged rations, either low, medium or high in their protein contents. Seven of the eight cows fed the low protein for nearly seven years was on hand for examination on the morning of July 8, 1913; four of the original lot which were started on the medium protein ration were in line; and only two of those which were set to work at the outset on the high protein ration were present.. However, no connection can be traced between the high mortality in the higher protein groups and the character of their feeding, for accident and death were responsible for the situation. Thus, for example, of those who fell by the wayside, two were killed by wires penetrating vital organs, four were sold being unprofitable or unruly or because of repeated abortion, two were dropped on account of age, one because she was barren and one because of frequent abortion. It is unfortunate, however, that the applicability of the results of the high protein trials, so far as they are to be determined by the scoring of the physical condition of the animals after long continued feeding, is so limited by the small number of survivors.

The names and the history of the cows which entered upon the long continuous feeding trials in December, 1906, and which at later dates were admitted to the trials, in so far as it concerns the dates of calving and drying off, appear on pages 19 to 22, and also in the earlier pages of bulletin 226; for in this portion of bulletin 225 the data accumulated as a result of feeding a considerable number of cows for a long series of years on unchanging rations in the maintenance trials can well be used, for the reason that they contribute testimony which is equally valuable to that afforded by the cows regularly enlisted in the long time protein trials.

**Low protein**

| No. | Name | Age | Years fed |
|---|---|---|---|
| 1 | Vt. Aster.. | 7 | 6 yrs., 2 mos. |
| 2 | Sheila .... | 12 | 6 " 4 " |
| 3 | Grace .... | 10 | 6 " 7 " |
| 4 | Fyra ..... | 11 | 5 " 10 " |
| 5 | Bontje .... | 10 | 5 " 9 " |
| 10 | Mab ...... | 7 | 6 " 2 " |
| 11 | Ardelle ... | 10 | 6 " 7 " |
| 12 | Aggie .... | 14 | 6 " 7 " |
| 13 | Hazel K... | 10 | 5 " 11 " |

Average age 10 yrs., 1 mo.

**Medium protein**

| No. | Name | Age | Years fed |
|---|---|---|---|
| 6 | Vt. Una... | 13 | 5 yrs., 1 mos. |
| 7 | Elbaje .... | 11 | 5 " 5 " |
| 8 | Altje ..... | 11 | 6 " 6 " |
| 14 | Angie .... | 8 | 5 " 11 " |
| 15 | Rocket ... | 7 | 6 " 1 " |
| | **High protein** | | |
| 16 | Sabra .... | 11 | 5 " 11 " |
| 9 | Yuba ..... | 14 | 6 " 7 " |
| 17 | Zeta ...... | 14 | 6 " 7 " |

Average ages 10 yrs., 2 mos.
14 yrs.

Each judge was asked to classify the cows on any and every sort of a basis that might occur to him. It was thought that in this manner the cows would be looked at from several angles, that the methods with which each man was most familiar would be used and that, since the final result secured in a measure would be of a composite nature, it might on that account be more trustworthy. The results of their deliberations are set forth in tabular form below, expressed on a percentage basis.

## TEXTURE OF SKIN AND HAIR

Three judges graded the animals upon basis of the texture of the skin and hair.

| | Low protein | | | | Medium protein | | | | High protein | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Judge's numbers | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average |
| Fine, soft and silky ....... | 22 | 33 | 22 | 26 | 17 | 17 | 33 | 22 | .. | 50 | .. | 17 |
| Medium ...... | 33 | 45 | 45 | 41 | 67 | 83 | 50 | 67 | 50 | 50 | 50 | 50 |
| Harsh and rough ...... | 45 | 22 | 33 | 33 | 17 | .. | 17 | 11 | 50 | .. | 50 | 33 |

In the 17 comparisons the three judges agreed independently in eight and two of the three agreed in nine cases. In but a single instance did a judge vary in his estimates as compared with those of his associates to the fullest possible extent; and this single instance, unfortunately, is located in the high protein group, making a discrepant result. In general, however, it is fairly safe to say that approximately a quarter of the cows in each lot were listed as fine skinned, a quarter as harsh skinned, while half of them were listed as intermediate in this respect; that, in short, no pronounced and positive outcome can be declared. Certainly the long continued feeding of the higher protein ration did not seem favorably to have affected the texture of the skin.

The following observations—very few in number—were made in connection with this examination. The feces and urine analyses represent one day's samples.

| | | Low protein | Medium protein | High protein |
|---|---|---|---|---|
| Average nitrogen content. | Hair | 9 cows 13.2 | 6 cows 13.3 | 2 cows 13.8 |
| Average ash content. | Hair | 9 cows 4 | 6 cows 3.5 | 2 cows 2.6 |
| Average nitrogen content. | Feces | 7 cows 2.2 | 2 cows 2.2 | 2 cows 2.3 |
| Average nitrogen content. | Urine | 7 cows 1.1 | 2 cows 1.4 | 2 cows 0.9 |

## MUSCULAR FIRMNESS

An increased muscular development, if brought about by feeding relatively large amounts of digestible protein, might perhaps be indicated by a firm, full loin, as well as by the firmness of the abdominal muscles. Three of the examiners passed judgment on this basis, two (Nos. 1 and 3) dealing with the loin, one (No. 2) with the abdominal muscles. In view of the fact that one judge classified in two and the others in three classes, it is difficult to determine averages which mean anything.

| | Low protein | | | Medium protein | | | High protein | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Firm and full.... | 22 | 45 | 11 | 50 | 67 | 33 | 50 | 50 | 50 |
| Medium ......... | .. | 33 | 67 | .. | 17 | 17 | .. | .. | .. |
| Thin (in loin) or soft (in abdominal muscles)... | 78 | 22 | 22 | 50 | 16 | 50 | 50 | 50 | 50 |

The results are widely dissimilar, both as regards the totals and the placing of the animals. No decided effect properly ascribable to past feeding practice could be found.

## THICKNESS OF SKIN

Two examiners studied the cows as to the thickness of their skin.

| | Low protein | | | Medium protein | | | High protein | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 4 | Average | 1 | 4 | Average | 1 | 4 | Average |
| Thick ....... | 67 | 33 | 50 | 17 | 17 | 17 | 50 | .. | 25 |
| Medium ..... | 22 | 22 | 22 | 83 | 33 | 58 | 50 | 50 | 50 |
| Thin ........ | 11 | 45 | 28 | .. | 50 | 25 | .. | 50 | 25 |

In seven cases the judges agreed and in 10 disagreed. Three of the disagreements were profound, one judge deeming a skin to be "thick" whereas the other called it "thin." Obviously nothing positive can be said as to the results.

### SKIN-TIGHTNESS—MUCOUS MEMBRANES

The tightness of the skin, the color of the mucous membrane of the vagina and of the eye were observed by one of the judges, who classified the cows on these cases as follows:

| Skin | Low protein | Medium protein | High protein |
|---|---|---|---|
| Tight | 33 | 17 | .. |
| Medium | 22 | 33 | 50 |
| Loose | 45 | 50 | 50 |

| Mucous membrane | Low protein | | Medium protein | | High protein | |
|---|---|---|---|---|---|---|
| Bright | 22 | 38 | 33 | 100 | .. | 50 |
| Medium | 56 | 37 | 33 | ... | 50 | .. |
| Pale | 22 | 25 | 33 | ... | 50 | 50 |

There seems to be a general tendency toward looseness of skin with the cows fed the higher protein ration; yet the indications are not sufficiently strong to amount to positive proof. The left hand side of table, however, furnishes the most consistent data thus far presented in indicating a difference in the physical condition of the animals eating a low protein ration as compared with those fed a large amount of protein. Little light can be gained from the study of the mucous membrane figures. Furthermore, there is little concordance between the hues of the two membranes, only seven of the 17 being similarly grouped.

### BEEF QUALITIES

The dressing-out properties, the general fatness, the butcher's basis of classification, was resorted to by two of the examiners, with results as follows:

| | Low protein | | | Medium protein | | | High protein | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | Average | 2 | 4 | Average | 2 | 4 | Average |
| Good ........ | 33 | 11 | 22 | 33 | 67 | 50 | 50 | .. | 25 |
| Medium ..... | 33 | 78 | 56 | 33 | .. | 33 | .. | 50 | 25 |
| Poor ........ | 33 | 11 | 22 | 33 | 33 | 33 | 50 | 50 | 50 |

If trust is placed in averages, most of the cows in the low protein group would be looked upon as medium beef, most of those in the medium protein groups as good beef, and most of those in the high protein group as poor beef. There seems no logical progression from good to poor or vice versa on the basis of the protein content of the rations.

A careful study of these results leads the writer to conclude that they lead nowhere; that nothing outstanding was noted by these several careful and expert observers as to the physical condition of these cows which justly might be interpreted to be due to the character of the feeding during a period of six and a half years; that neither those fed high protein nor those fed low protein rations seemed to have suffered physically as a result.

In view of the fact that each of the several examiners was asked to find trouble, if it was possible to do so, this outcome seems significant.

## THE 1914 EXAMINATION

The examination of July 8, 1913 having revealed no distinct differences in the physical condition of the cows fed low, medium and high protein rations, it seemed advisable to repeat the work a year later in view of the fact that the trials were to be reshaped in the late fall and a number of the older cows discarded. Hence a second survey was made on September 21.

The following table shows the arrangement, the age of each cow and the number of years each cow had been fed continuously on a particular ration.

Low protein

| No. | Name | Age | Years fed |
|---|---|---|---|
| 1 | Sheila | 13 | 7 yrs., 6 mos. |
| 6 | Ardelle | 11 | 7 " 9 " |
| 7 | Fyra | 12 | 7 " 1 " |
| 12 | Grace | 11 | 7 " 9 " |
| 13 | Mab | 8 | 7 " 4 " |
| 18 | Vt. Aster | 8 | 7 " 5 " |
| 22 | Bontje | 11 | 7 " .. " |
| 23 | Evelyn | 7 | 2 " .. " |
| 28 | Effa | 6 | 1 " 3 " |
| 29 | Lanta | 12 | 4 " 10 " |

Average age 9.9 yrs.

Medium protein

| No. | Name | Age | Years fed |
|---|---|---|---|
| 2 | Angie | 9 | 7 yrs., 1 mos. |
| 5 | Rocket | 8 | 7 " 4 " |
| 8 | Elbaje | 12 | 6 " 7 " |
| 11 | Isadore | 7 | 1 " 11 " |
| 14 | Karah | 4 | 1 " 9 " |
| 17 | Vt. Ivis | 6 | 1 " 10 " |
| 19 | Ryllis | 6 | 1 " 11 " |
| 21 | Altje | 12 | 7 " 2 " |
| 24 | Lanta 2nd. | 6 | 2 " 1 " |
| 27 | Mary | 6 | 2 " 4 " |

Average age 7.6 yrs.

High protein

| No. | Name | Age | Years fed |
|---|---|---|---|
| 3 | Beatrice | 7 | .. yr., 7 mos. |
| 4 | Electa | 5 | 1 " 10 " |
| 9 | Phoebe | 5 | 1 " 11 " |
| 10 | Hepsy | 7 | 1 " 11 " |
| 15 | Vic | 4 | .. " 11 " |
| 16 | Vt. Peony | 5 | 1 " 11 " |
| 20 | Fizzy | 3 | 1 " .. " |
| 25 | Dell R. | 5 | 1 " 4 " |
| 26 | Nesbit | 6 | 1 " 9 " |

Average age 5.2 yrs.

Six of the original lot fed the low protein ration, which started on the long road in December, 1906, were present; four of those fed the medium protein ration were in line; but not one of those which began in 1906 to feed upon the high protein ration answered to the roll call.

The judges were requested first to classify the cows into three groups, on whatsoever basis they felt would be likely to afford opportunity for adequate judgment. Accordingly, in the first place they grouped them on the basis of the general impression obtained by looking at the animals, i. e., their vitality, thrift, evidences of proper nourishment, etc. There were placed as follows:

GENERAL APPEARANCE

| Low protein | Good | Medium | Poor | Medium protein | Good | Medium | Poor | High protein | Good | Medium | Poor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ardelle | .. | .. | 2 | Altje | .. | .. | 2 | Beatrice | 1 | 1 | .. |
| Vt. Aster | 2 | .. | .. | Angie | 2 | .. | .. | Dell R. | 2 | .. | .. |
| Bontje | .. | 1 | 1 | Elbaje | 1 | 1 | .. | Electa | 1 | 1 | .. |
| Effa | 2 | .. | .. | Isadore | .. | 1 | 1 | Fizzy | 1 | 1 | .. |
| Evelyn | .. | .. | 2 | Karah | .. | 2 | .. | Hepsey | 2 | .. | .. |
| Fyra | .. | 1 | 1 | Lanta 2nd | .. | 1 | 1 | Nesbit | 2 | .. | .. |
| Grace | .. | .. | 2 | Mary | .. | 2 | .. | Poebe | 1 | 1 | .. |
| Lanta | .. | .. | .. | Rocket | 1 | 1 | .. | Vt. Peony | .. | .. | 2 |
| Mab | 2 | .. | .. | Ryllis | .. | 2 | .. | Vic | .. | .. | 2 |
| Sheila | .. | 1 | 1 | Vt. Ivis | 2 | .. | .. | | | | |
| Totals | 6 | 3 | 9 | | 6 | 10 | 4 | | 10 | 4 | 4 |
| Total % | 33 | 17 | 50 | | 30 | 50 | 20 | | 55 | 22 | 23 |

Seventeen were similarly and 11 dissimilarly placed. In no case did the judges disagree so widely that a cow adjudged "good" by one was deemed "poor" by the other.

There seems to be ground for claiming that there were some differences in the external appearance of the cows fed different amounts of protein. Half of the cows fed a low protein diet gave the judges a poor impression from the standpoint of thrift, vitality, nutrition, etc.; half of those fed medium protein rations were listed in the medial class; and half of those fed the higher protein ration were deemed to be "good." In other words, in each case at least one-half of the cows in a given group were bunched, as it were, in a particular class. There seems to be a logical progression from "poor" to "good" roughly in accordance with the amount of protein consumed.

However, too much stress should not be laid upon this fact. The age of the cows in each class may have had something to do with this outcome. Owing to accidents and death (see page 70) the original group of cows fed the high protein ration had passed away and their places had been taken from time to time by younger animals, the average age of the new comers being 6.2 years. None of these had been under trial for as long a period as two years. Only four of nine of the original group fed a medium protein ration were left, and these together with six younger cows composed the 1914 group. Their average age was 8.6 years. Seven of the original nine cows fed a low protein diet remained and only two younger cows had been associated with them; hence their average age was 10.7 years.

Quite apart from considerations of ration influence, it is obvious that a group of cows nearly 11 years old would not be as likely to find favor in the eyes of cattle judges, so far as apparent thrift and vitality are concerned, as would a group but six years old and in their prime.

If a comparison is instituted using only the cows that had been continuously fed since 1906, the tendency appears to be somewhat similar. The cows fed a low protein diet do not appear to quite as good advantage as do those receiving the medium protein ration. However, in view of their small numbers, one naturally hesitates to draw sweeping conclusions or to dogmatize.

| | |
|---|---|
| Low protein: | Good 29%; medium 20%; poor 50%. |
| Medium protein: | Good 50%; medium 25%; poor 25%. |
| High protein: | None left. |

One-half of the original low protein group is classified as "poor," while two of the four cows fed a medium protein ration are deemed "good." Yet representatives of both the low and the medium protein groups are found in each class. It would seem that while the cows eating daily for eight years a medium protein ration possibly appeared to better advantage as judged by general appearance than did those fed a lower protein ration, this tendency was neither distinct nor conclusive.

## THICKNESS OF SKIN

Protein being an important constituent of the structure of the skin, it seemed reasonable to expect that a comparison of the thickness of the skin of the several animals might serve to betray differences, if any such there were. To this phase of the examination especial attention was paid, in view of the fact that the relative thickness of the skins of the experimentally fed animals in the Minnesota trials[1] was the means whereby the cows fed a low protein diet for a portion only of each of a few years unerringly were identified by a single observer (see page 175). The results follow:

| Low protein | Thick | Medium | Thin | Medium protein | Thick | Medium | Thin | High protein | Thick | Medium | Thin |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ardelle | 1 | 1 | .. | Altje | 1 | 1 | .. | Beatrice | .. | .. | 2 |
| Vt. Aster | .. | 1 | 1 | Angie | 1 | .. | 1 | Dell R. | 1 | 1 | .. |
| Bontje | 1 | 1 | .. | Elbaje | .. | .. | 2 | Electa | 2 | .. | .. |
| Effa | .. | 1 | 1 | Isadore | 1 | 1 | .. | Fizzy | .. | 1 | 1 |
| Evelyn | 2 | .. | .. | Karah | .. | 1 | 1 | Hepsey | 1 | 1 | .. |
| Fyra | .. | .. | 2 | Lanta 2nd | 2 | .. | .. | Nesbit | 2 | .. | .. |
| Grace | 2 | .. | .. | Mary | 1 | 1 | .. | Phoebe | 1 | 1 | .. |
| Mab | .. | 1 | 1 | Rocket | .. | .. | 2 | Vt. Peony | .. | 2 | .. |
| Sheila | .. | 1 | 1 | Ryllis | .. | 2 | .. | Vic | 2 | .. | .. |
| | | | | Vt. Ivis | .. | 2 | .. | | | | |
| Total | 6 | 6 | 6 | | 6 | 8 | 6 | | 9 | 6 | 3 |
| Total % | 33 | 34 | 33 | | 30 | 40 | 30 | | 50 | 33 | 17 |

In 13 cases the judges agreed in clasification, that is to say, they were a unit in declaring that, for example, Evelyn was a thin-skinned cow; in 14 cases the judges disagreed to the extent of a single class, one deeming Ardelle to be a thin-skinned cow, while the other considered her to be a medum-skinned animal; and in one case, Angie, one judge considered that the cow had a thin skin whereas the other held that her skin was thick. There seems little if any correlation between the amount of protein consumed and the thickness of the skin. One-third of the cows fed the low protein ration were placed in each class; those eating a medium protein diet were also almost equally divided among the three classes; whereas the cows eating a high protein ration on the whole were deemed to be somewhat thicker skinned than their mates. In other words, a relatively heavy protein diet seemed to tend somewhat to increase the protein deposits in the form of skin. However, it will not do to overstress this observation for usually the uniformity of the distribution of the cows continuously fed for nearly eight years on a low protein diet among the several groups is significant as negative evidence.

Even less correlation between protein ingestion and the thickness of skin is observed if, discarding the new comers, only those records are taken into account which were made by cows that had been continuously fed on a single diet for the entire period of eight years.

---

[1] Loc. cit., pp. 173-177.

| | |
|---|---|
| **Low protein:** | **Thick 29%; medium 35%; thin 36%.** |
| **Medium protein:** | **Thick 25%; medium 13%; thin 62%.** |
| **High protein:** | **None left.** |

In four cases the judges agreed, in six they disagreed and in one case they disagreed profoundly. So far as the charter members of the herd are concerned, those cows which had been at work since the beginning of the experiment eight years before, it would appear that those fed a low protein diet were quite evenly distributed among the three groups as classified by their skin texture and that, as compared with those fed a medium protein ration, they were not conspicuous for their thinness of skin; indeed, if anything, the reverse was true. None of the original high protein cows were left at this time. In short, it does not appear from the foregoing tables that cows fed a low protein ration were thinner of skin than those fed a higher protein ration.

The cows were then brought before the judges in pairs, in order to give still further opportunity for classification. Each judge was requested to decide in each case which of the two animals then before him had the thicker skin. The cows which had received a low protein diet were first paired off against those which had been fed the medium protein ration; then the latter against their associates which had eaten a high protein ration; and, finally, the cows fed low protein were pitted against those fed high protein rations. The results follow, the cow whose name is italicized being held to have the thicker skin of the two:

| Low protein | Medium protein | Medium protein | High protein | Low protein | High protein |
|---|---|---|---|---|---|
| Sheila | *Angie* | *Angie* | Beatrice | Sheila | *Beatrice* |
| *Ardelle* | Rocket | Rocket | *Electa* | Ardelle | *Electa* |
| *Fyra* | Elbaje | Elbaje | *Phoebe* | Tyra | *Phoebe* |
| *Grace* | Isadore | Isadore | *Hepsy* | Grace | *Hepsy* |
| *Mab* | Karah | Karah | *Vic* | Mab | *Vic* |
| Vt. Aster | *Vt. Ivis* | *Vt. Ivis* | Vt. Peony | Vt. Aster | *Vt. Peony* |
| Bontje | *Altje* | *Ryllis* | Fizzy | *Evelyn* | Dell R. |
| Evelyn | *Lanta 2nd* | *Lanta 2nd* | Dell R. | Effa | *Nesbit* |
| Effa | *Mary* | Mary | *Nesbit* | *Lanta 2nd* | Dell R. |

In the first instance, five of nine, in the second, seven of nine, and in the third, six of nine comparisons tally with the independent observations previously made. For example, Ardelle's skin was classified as medium to thick, Rocket's as thin; and when directly compared the former's skin was deemed to be thicker.

In nine cases, the hides of the competing animals had been classified in the same group in the previous examination.

In the first instance, the cows fed the larger amount of protein seemed to have thicker skins in six cases and thinner skins in four cases. There is certainly little evidence here indicating correlation between the amount of protein fed and the thickness of the skin. If one were to feed 10 pairs of cows exactly the same ration, the comparison could not be more equally divided.

Furthermore, limiting the comparison solely to those animals which had been upon experiment for eight years (the first, second, third and seventh pairs), it appears that in two cases the cows fed the medium protein ration had the thicker skins, while in the other two cases the cows fed the low protein ration had the thicker skins.

In the second instance, in five out of nine pairs the cows fed the high protein ration wore the thicker skin. This is as even a division as could possibly exist. Again no correlation appears.

In the third case, in seven out of nine cases the cows fed the high protein ration had the thicker skins. This would appear to constitute fairly consistent evidence in favor of the proposition that the cows fed the higher protein ration might be expected to have thicker skins. However, the possible influence of the difference in age of the two groups should not be forgotten. As has already been stated, all the original high protein cows had fallen out and their places were filled from time to time with younger animals. As has been previously said—and is here repeated lest misunderstanding arise—these removals do not seem to bear relation to the nature of the ration which was fed. Accidents and other troubles not properly chargeable to the feed were largely responsible for the depletion of the high protein group (see page 70). In this particular classification the first six animals of the low protein group were the old cows that started with the experiment; and in every case their hides were deemed to be thinner than those which clad their younger sisters fed the more proteinous ration.

Combining all the results as displayed in these three comparisons, it appears that in 18 of the 28 pairs the cows fed the higher protein ration possessed the thicker skins. This result is certainly not conclusive enough to warrant dogmatic assertion as to correlation.

### HAIR, UDDER, MUCOUS MEMBRANES

One judge classified the cows according to the texture of the hair, the correctness of type of the udder and the color of the mucous membranes of the eye, nose, etc., with results as follows:

| Hair | Low protein | Medium protein | High protein | Udder | Low protein | Medium protein | High protein | Mucous membranes | Low protein | Medium protein | High protein |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fine | 45 | 20 | 33 | Good | 33 | 40 | 22 | Red | 30 | 30 | 41 |
| Medium | 22 | 40 | 45 | Medium | 22 | 40 | 11 | Medium | 33 | 30 | 33 |
| Coarse | 33 | 40 | 22 | Poor | 45 | 20 | 67 | Pale | 37 | 40 | 26 |

Hair. No correlation appears.

Udder. No correlation appears. The udders of several of the cows fed low and high protein rations were inferior.

Mucous membranes. No correlation appears.

### FINAL COMPARISON BY PAIRS

Finally, the cows were again brought before the judges in pairs. Each judge was requested to take into account all possible factors relating to the physical condition of the animals and then to state which one of the pair in his opinion had received the higher protein ration. The cows which had eaten the low protein were first paired off against those fed the medium protein ration, then the latter against the cows fed the high protein ration, and, finally, the first named against the last named. The results follow:

| | Low protein | | Medium protein | 1 | 2 |
|---|---|---|---|---|---|
| 1 | Sheila | 2 | Angie | right | right |
| 6 | Ardelle | 5 | Rocket | wrong | right |
| 7 | Fyra | 8 | Elbaje | right | right |
| 12 | Grace | 11 | Isadore | wrong | right |
| 13 | Mab | 14 | Karah | right | wrong |
| 18 | Vt. Aster | 17 | Vermont Ivis | right | right |
| 22 | Bontje | 21 | Altje | right | right |
| 23 | Evelyn | 24 | Lanta 2nd | no choice | wrong |
| 28 | Effa | 27 | Mary | wrong | wrong |
| 29 | Lanta | 24 | Lanta 2nd | overlooked | wrong |

| | Medium protein | | High protein | 1 | 2 |
|---|---|---|---|---|---|
| 2 | Angie | 3 | Beatrice | no choice | wrong |
| 5 | Rocket | 4 | Electa | right | wrong |
| 8 | Elbaje | 9 | Phoebe | right | no choice |
| 11 | Isadore | 10 | Hepsy | no choice | right |
| 14 | Karah | 15 | Vic | right | wrong |
| 17 | Vermont Ivis | 16 | Vermont Peony | no choice | wrong |
| 19 | Ryllis | 20 | Fizzy | no choice | right |
| 24 | Lanta 2nd | 25 | Dell R. | no choice | right |
| 27 | Mary | 26 | Nesbit | right | wrong |

| | Low protein | | High protein | 1 | 2 |
|---|---|---|---|---|---|
| 1 | Sheila | 3 | Beatrice | no choice | right |
| 6 | Ardelle | 4 | Electa | right | wrong |
| 7 | Fyra | 9 | Phoebe | no choice | wrong |
| 12 | Grace | 10 | Hepsy | no choice | right |
| 13 | Mab | 15 | Vic | right | wrong |
| 18 | Vt. Aster | 16 | Vermont Peony | no choice | right |
| 23 | Evelyn | 25 | Dell R. | no choice | right |
| 28 | Effa | 26 | Nesbit | right | wrong |
| 29 | Lanta | 25 | Dell R. | overlooked | right |

Totalling these results, it appears that one judge placed 12 pairs correctly, could detect no differences in 11 cases and was wrong in his judgment three times in 26; and that the other judge placed 14 pairs correctly, 13 pairs incorrectly, stating in two instances that the choice was a narrow one, and in one case could make no choice.

Summing up all the evidence secured in this second physical examination, it would certainly appear that little if any correlation was observed between the amount of protein fed and the physical condition of the animal. When an expert judge can pick out the cows fed the higher protein ration in but 12 out of 26 pairs brought before him for comparison and another expert judge but 14 pairs out of 28, it certainly would appear that the variations in protein rationing in these particular trials were not important factors in the maintenance of the physical condition of the cows.

## THE 1916 EXAMINATION

The two previous examinations revealed no distinct differences in the physical condition of the cows fed the low, medium and high protein rations. A still lower protein ration was introduced into the trials in October, 1914. Hence it was deemed advisable to examine the cows a third time before turning them to pasture. It is fair to expect after cows have been on pasture for a time, even on so very scanty a pasture as that available on the University farm, that there may be a tendency manifested in the direction of overcoming to some extent the depressing effects, if any such there be, which may be wrought by insufficient or ill-balanced rations.

The following cows were examined:

**Very low protein ration**

| | | Years in test | | | |
|---|---|---|---|---|---|
| 1 | Granny .... | 1 | year, | 8 | months |
| 2 | Katydid .... | 1 | " | 8 | " |
| 3 | Phoebe ..... | 1 | " | 8 | " |
| 4 | Rena ....... | 1 | " | 1 | " |
| 5 | Ryllis ...... | | | 11 | " |
| 6 | Vic ......... | 1 | " | 3 | " |
| 7 | Vt. Peony .. | 1 | " | 3 | " |

**Low protein ration**

| | | Years in test | | | |
|---|---|---|---|---|---|
| 8 | Ardelle .... | 9 | years, | 10 | months |
| 9 | Grace ..... | 9 | " | 10 | " |
| 10 | Effa ....... | 3 | " | 4 | " |
| 11 | Lanta ..... | 6 | " | 11 | " |
| 12 | Karah ..... | 1 | " | 5 | " |
| 13 | Kinky .... | 1 | " | 8 | " |
| 14 | Dot ....... | 2 | " | 6 | " |
| 15 | Evelyn .... | 4 | " | 8 | " |

| | Medium protein ration | Years in test | | | High protein ration | Years in test | |
|---|---|---|---|---|---|---|---|
| 16 | Isadore .... | 4 years, | 1 month | 20 | Hepsy ..... | 4 years | |
| 17 | Lanta 2nd.. | 4 " | 2 months | 21 | Fizzy ...... | 3 " | 1 month |
| 18 | Mary ...... | 4 " | 5 months | 22 | Dell R. .... | 3 " | 5 months |
| 19 | Vinegar ... | 1 " | 2 months | 23 | Nesbit ..... | 3 " | 10 months |
| | | | | 24 | Augusta ... | 1 year | |

### GENERAL APPEARANCE

In judging the general appearance of the cows, condition, thrift and other external factors making up a well nourished animal were considered. The following table sets forth the results of the separate placing by the four judges:

| Very low | Good | Medium | Poor | Low | Good | Medium | Poor | Medium | Good | Medium | Poor | High | Good | Medium | Poor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granny | 3 | 1 | .. | Ardelle | 2 | 2 | .. | Isadore | 1 | 2 | 1 | Augusta | .. | 2 | 2 |
| Katydid | 1 | 3 | .. | Dot | 3 | 1 | .. | Lanta 2nd | 3 | 1 | .. | Dell R. | 3 | 1 | .. |
| Phoebe | 3 | 1 | .. | Effa | .. | 2 | 2 | Mary | .. | 4 | .. | Fizzy | 4 | .. | .. |
| Rena | 2 | 2 | .. | Evelyn | 1 | .. | 3 | Vinegar | .. | 2 | 2 | Hepsy | 1 | 3 | .. |
| Ryllis | 4 | .. | .. | Grace | .. | 1 | 3 | | | | | Nesbit | .. | .. | 4 |
| Vt. Peony | .. | 3 | 1 | Karah | 1 | 2 | 1 | | | | | | | | |
| Vic | 2 | 1 | 1 | Kinky | 4 | .. | .. | | | | | | | | |
| | | | | Lanta | 1 | 1 | 2 | | | | | | | | |
| Total | 15 | 11 | 2 | | 12 | 9 | 11 | | 4 | 9 | 3 | | 8 | 6 | 6 |
| Total % | 54 | 39 | 7 | | 38 | 28 | 34 | | 25 | 56 | 19 | | 40 | 30 | 30 |

These data should be considered in connection with a statement as to the length of time of feeding on these several rations, which were, on the average, very low protein ration 1⅜ years; low protein ration 4¾ years; medium protein ration 3¼ years; high protein ration 2⅘ years. Now, while there is no very marked trend in any direction, the cows fed the very low ration as a class looked distinctly better to the judges than the others, but they had been fed this ration for a relatively short time and they were, moreover, as a whole a younger lot of cows than their competitors, the average approximate ages being: very low protein ration, 7 years; low protein ration, 10 years; medium protein ration, 8 years; high protein ration, 9 years. There does not seem to be any pronounced effect upon general condition which justly may be ascribed to the nature of the feeding.

### THICKNESS OF SKIN

The thickness of the skin was studied by manual manipulation and by actual measurements by means of calipers applied to each animal at the last rib half way down the body, the skin being pulled up and a piece of iron pressed on each side back of the fold. The results secured by the two methods of comparison are presented in the following tables:

| Very low | Thick | Medium | Thin | Low | Thick | Medium | Thin | Medium | Thick | Medium | Thin | High | Thick | Medium | Thin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Granny** | .. | 4 | .. | **Ardelle** | .. | 1 | 3 | **Isadore** | .. | .. | 4 | **Augusta** | 2 | 2 | .. |
| **Katydid** | .. | 3 | 1 | **Dot** | 1 | 2 | 1 | **Lanta 2nd** | 3 | 1 | .. | **Dell R.** | 1 | 2 | 1 |
| **Phoebe** | .. | 2 | 2 | **Effa** | .. | 3 | 1 | **Mary** | 2 | 1 | 1 | **Fizzy** | .. | 2 | 2 |
| **Rena .** | .. | 4 | .. | **Evelyn** | 4 | .. | .. | **Vinegar** | 4 | .. | .. | **Hepsy** | 4 | .. | .. |
| **Ryllis** | .. | .. | 4 | **Grace** | .. | 4 | .. | | | | | **Nesbit** | 4 | .. | .. |
| **Vt. Peony** | .. | 4 | .. | **Karah** | .. | 1 | 3 | | | | | | | | |
| **Vic** | 3 | 1 | .. | **Kinky** | .. | .. | 4 | | | | | | | | |
| | | | | **Lanta** | 3 | 1 | .. | | | | | | | | |
| **Total** | 3 | 18 | 7 | | 8 | 12 | 12 | | 9 | 2 | 5 | | 11 | 6 | 3 |
| **Total %** | 11 | 64 | 25 | | 25 | 38 | 37 | | 56 | 13 | 31 | | 55 | 30 | 15 |

| | **Thick 27-64 to 34-64** | | | **Medium 24-64 to 26-64** | | | **Thin 20-64 to 23-64** | |
|---|---|---|---|---|---|---|---|---|
| 6 | **Vic** ......... | 27-64 | 13 | **Kinky** ........ | 24-64 | 8 | **Ardelle** ..... | 20-64 |
| 17 | **Lanta 2nd** ... | 28-64 | 7 | **Vermont Peony** | " | 12 | **Karah** ...... | " |
| 19 | **Vinegar** ..... | " | 4 | **Rena** .......... | " | 21 | **Fizzy** ....... | 22-64 |
| 11 | **Lanta** ....... | 30-64 | 9 | **Grace** ......... | " | 5 | **Ryllis** ....... | " |
| 23 | **Nesbit** ...... | 32-64 | 14 | **Dot** ........... | " | 16 | **Isadore** ..... | " |
| 20 | **Hepsy** ...... | 34-64 | 22 | **Dell R.** ......... | " | 2 | **Katydid** ..... | " |
| 15 | **Evelyn** ...... | " | 24 | **Augusta** ...... | 25-64 | | | |
| | | | 1 | **Granny** ....... | " | | | |
| | | | 3 | **Phoebe** ........ | 26-64 | | | |
| | | | 18 | **Mary** ......... | " | | | |
| | | | 10 | **Effa** .......... | " | | | |

The two summaries are quite concordant. It seems reasonably clear that the hides of the cows which were fed the larger amounts of protein tended to be somewhat thicker than those fed the lesser amounts, although the differences in the ages and lengths of time which the cows had been fed their respective rations should be borne in mind. Certain it is that these results do not in the least bear out the contention of those who claim to be able to tell the cows fed a relatively proteinous ration from those fed a relatively wide ration by the comparative thinness of the skin of the former.

## TEXTURE OF HAIR

Careful note was taken as to the texture and condition of the hair. The placements were as follows:

| Very low | Fine | Medium | Coarse | Low | Fine | Medium | Coarse | Medium | Fine | Medium | Coarse | High | Fine | Medium | Coarse |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granny | 1 | 3 | .. | Ardelle | 2 | 2 | .. | Isadore | 3 | 1 | .. | Augusta | .. | 3 | 1 |
| Katydid | 1 | 2 | 1 | Dot | 1 | 2 | 1 | Lanta 2nd | 1 | 3 | .. | Dell R. | 3 | 1 | .. |
| Phoebe | 2 | 2 | .. | Effa | .. | 4 | .. | Mary | .. | 2 | 2 | Fizzy | 2 | 2 | .. |
| Rena | 2 | 2 | .. | Evelyn | .. | 1 | 3 | Vinegar | 1 | 3 | .. | Hepsy | .. | 4 | .. |
| Ryllis | 2 | 2 | .. | Grace | .. | 3 | 1 | | | | | Nesbit | 1 | .. | 3 |
| Vt. Peony | .. | 3 | 1 | Karah | 1 | 2 | 1 | | | | | | | | |
| Vic | 3 | 1 | .. | Kinky | 3 | 1 | .. | | | | | | | | |
| | | | | Lanta | .. | 1 | 3 | | | | | | | | |
| Total | 11 | 15 | 2 | | 7 | 16 | 9 | | 5 | 9 | 2 | | 6 | 10 | 4 |
| Total % | 39 | 54 | 7 | | 22 | 50 | 28 | | 31 | 56 | 13 | | 30 | 50 | 20 |

The summary seems to indicate that heavy feeding with protein does not necessarily tend to produce a finer quality of hair and that on the other hand a low protein ration does not necessarily tend to produce coarse hair. However, since hair is a modified skin structure and highly nitrogenous in its nature and since the coarser the hair the more the nitrogen, the data secured with the cows fed the very low protein ration seems a bit significant. Of old it was said that bricks could not be made successfully without straw; and these cows fed the very low protein ration were not abundantly supplied with the wherewithal to construct a heavy hirsute covering. On the other hand, it should be remembered that this lot as a whole was somewhat younger than the others. Over half of the cows of all groups fell within the medium class.

## MUCOUS MEMBRANES

An examination of the mucous membranes of the various cattle resulted in the following placement by two of the judges

| Very low | Red | Normal | Pale | Low | Red | Normal | Pale | Medium | Red | Normal | Pale | High | Red | Normal | Pale |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granny | 2 | .. | .. | Ardelle | .. | 2 | .. | Isadore | .. | 2 | .. | Augusta | .. | .. | 2 |
| Katydid | .. | 2 | .. | Dot | .. | 2 | .. | Lanta 2nd | .. | 2 | .. | Dell R. | .. | .. | 2 |
| Phoebe | 2 | .. | .. | Effa | .. | .. | 2 | Mary | .. | .. | 2 | Fizzy | .. | .. | 2 |
| Rena | .. | .. | 2 | Evelyn | 2 | .. | .. | Vinegar | .. | 2 | .. | Hepsy | .. | 2 | .. |
| Ryllis | .. | 2 | .. | Grace | .. | 2 | .. | | | | | Nesbit | 1 | 1 | .. |
| Vt. Peony | .. | 1 | 1 | Karah | .. | 2 | .. | | | | | | | | |
| Vic | .. | .. | 2 | Kinky | 2 | .. | .. | | | | | | | | |
| | | | | Lanta | .. | .. | 2 | | | | | | | | |
| Total | 4 | 5 | 5 | | 4 | 8 | 4 | | 0 | 6 | 2 | | 1 | 3 | 6 |
| Total % | 28 | 36 | 36 | | 25 | 50 | 25 | | 0 | 75 | 25 | | 10 | 30 | 60 |

The results would seem to indicate that cows getting the lower protein rations as a whole had highly colored mucous membranes, whereas the membranes of those cows getting the larger amounts were, as a whole, more pale than red. This fact might be accounted for physiologically, however, in view of the fact that the herd is infected with granular vaginitis. This particular observation probably has little value.

### BODY TEMPERATURES

It was suggested that comparisons might be made to advantage of body surface temperatures, as noted by the hand passing over the skin, with an average of 36-hour internal temperatures. The latter data were arbitrarily classified as: warm 102-101.5; medium 101.4-101.2; cool 101.1-100.9. The results are displayed in tabular form as follows:

| Very Low | Warm | Medium | Cool | Average temperature 36 hours ° F. |
|---|---|---|---|---|
| Granny | .. | 2 | 2 | 101.4 |
| Katydid | .. | 4 | .. | 101.1 |
| Phoebe | 4 | .. | .. | 101.2 |
| Rena | 3 | 1 | .. | 101.3 |
| Ryllis | 1 | 3 | .. | 103 |
| Vt. Peony | .. | 4 | .. | 101.8 |
| Vic | 3 | .. | 1 | 101.1 |
| Totals | 11 | 14 | 3 | 101.43 |
| Totals % | 39 | 50 | 11 | |

| Low | Warm | Medium | Cool | Average temperature 36 hours ° F. |
|---|---|---|---|---|
| Ardelle | 3 | 1 | .. | 101.1 |
| Dot | 1 | 1 | 2 | 101.8 |
| Effa | .. | 2 | 2 | 101 |
| Evelyn | .. | 2 | 2 | 100.9 |
| Grace | .. | 3 | 1 | 101.1 |
| Karah | .. | 3 | 1 | 101.3 |
| Kinky | 4 | .. | .. | 101.4 |
| Lanta | .. | 2 | 2 | 101.2 |
| | 8 | 14 | 10 | 101.23 |
| | 25 | 44 | 31 | |

| Medium | Warm | Medium | Cool | Average temperature 36 hours ° F. |
|---|---|---|---|---|
| Isadore | .. | 2 | 2 | 101.2 |
| Lanta 2nd | 1 | 1 | 2 | 101.4 |
| Mary | .. | 2 | 2 | 100.9 |
| Vinegar | .. | 1 | 3 | 101.3 |
| Totals | 1 | 6 | 9 | 101.2 |
| Totals % | 6 | 38 | 56 | |

| High | Warm | Medium | Cool | Average temperature 36 hours ° F. |
|---|---|---|---|---|
| Augusta | .. | 1 | 3 | 101.4 |
| Dell R. | 1 | 3 | .. | 101.3 |
| Fizzy | .. | 4 | .. | 101.1 |
| Hepsy | 1 | 2 | 1 | 101.1 |
| Nesbit | 3 | .. | 1 | 100.9 |
| | 5 | 10 | 5 | 101.16 |
| | 25 | 50 | 25 | |

As judged by manual observation the cows fed the lower protein rations, and especially those fed the very low one, displayed somewhat higher body temperatures than did those fed the narrower rations. This was evident not only as a result of personal judgment, but was testified by the thermometer. The cows fed the very wide ration were relatively a warm bunch and those fed the narrow one relatively a cool proposition. It is believed among cattle feeders that cows fed a wide ration, as compared with those fed narrow rations, tend to exhibit somewhat higher temperatures, but it has not been supposed that this effect would be of necessity culminative in character; nor is it so claimed in this case. It may well be that as great differences might have been observed as between cows fed on comparable rations for only a short time.

### PAIRING

After examining the cows for general appearance, thickness of skin, quality of hair, surface temperature and the like, they were brought before the judges in pairs in order to determine, if possible, what differences, if any, existed between cows of the different groups. Comparisons were made between the very low and low, the very low and medium, the very low and high, the low and medium, the low and high, and the medium and high groups. These pairs were made up at random and as many combinations of all sorts were constructed as possible. In making their choices, the judges knew nothing whatsoever as to which of the two animals had been fed the ration containing the larger amount of protein. In fact, they knew very little regarding the history of the experiment, other than its bare outline. They were asked to choose in each case the cow which appeared better nourished and which seemed to be physiologically the more nearly normal. A summary of their placings follows, arranged in the order in which the pairs were presented. Only three judges were used in their instance, for one of the four, in charge of the trial, was naturally well acquainted with the history of each cow.

It should be noted in this connection that as these results are expressed, the words "lower" and "higher" are used in a different sense than elsewhere, only to distinguish between the two cows of the several pairs, and are not strictly in accordance with usage in other parts of this bulletin. Thus, for example, in the first comparison "the higher" fed cow was Ardelle, fed a low protein ration, and in the sixth "the lower" fed cow was Isadore, fed a medium protein ration.

| The lower fed[1] | | | The higher fed[1] | | Deemed to be the better nourished | | |
|---|---|---|---|---|---|---|---|
| | | | | | By judge 1 | By judge 2 | By judge 3 |
| 1 | Granny (VL) | vs. | 8 | Ardelle (L) | Granny | Granny | Granny |
| 1 | Granny (VL) | vs. | 16 | Isadore (M) | Granny | Granny | Granny |
| 1 | Granny (VL) | vs. | 20 | Hepsy (H) | Granny | Granny | Granny |
| 8 | Ardelle (L) | vs. | 16 | Isadore (M) | Ardelle | Isadore | Ardelle |
| 8 | Ardelle (L) | vs. | 20 | Hepsy (H) | Ardelle | Hepsy | Hepsy |
| 16 | Isadore (M) | vs. | 20 | Hepsy (H) | Isadore | Hepsy | Hepsy |
| 2 | Katydid (VL) | vs. | 9 | Grace (L) | Katydid | Katydid | Katydid |
| 2 | Katydid (VL) | vs. | 17 | Lanta 2nd (M) | Lanta 2nd | Lanta 2nd | Lanta 2nd |
| 2 | Katydid (VL) | vs. | 21 | Fizzy (H) | Fizzy | Fizzy | Katydid |
| 9 | Grace (L) | vs. | 17 | Lanta 2nd (M) | Lanta 2nd | Lanta 2nd | Lanta 2nd |
| 9 | Grace (L) | vs. | 21 | Fizzy (H) | Fizzy | Fizzy | Fizzy |
| 17 | Lanta 2nd (M) | vs. | 21 | Fizzy (H) | Fizzy | Lanta 2nd | Lanta 2nd |
| 3 | Phoebe (VL) | vs. | 10 | Effa (L) | No choice | Phoebe | Phoebe |
| 3 | Phoebe (VL) | vs. | 18 | Mary (M) | Phoebe | Phoebe | Phoebe |
| 3 | Phoebe (VL) | vs. | 22 | Dell R. (H) | Dell R. | Dell R. | Dell R. |
| 10 | Effa (L) | vs. | 18 | Mary (M) | Effa | Mary | Mary |
| 10 | Effa (L) | vs. | 22 | Dell R. (H) | Dell R. | Dell R. | Dell R. |
| 18 | Mary (M) | vs. | 22 | Dell R. (H) | Dell R. | Mary | Mary |
| 4 | Rena (VL) | vs. | 11 | Lanta (L) | Rena | Lanta | Rena |
| 4 | Rena (VL) | vs. | 19 | Vinegar (M) | No choice | Rena | Rena |
| 4 | Rena (VL) | vs. | 23 | Nesbit (H) | Rena | Rena | Rena |
| 11 | Lanta (L) | vs. | 19 | Vinegar (M) | Vinegar | Lanta | Vinegar |
| 11 | Lanta (L) | vs. | 23 | Nesbit (H) | Lanta | Lanta | Lanta |
| 19 | Vinegar (M) | vs. | 23 | Nesbit (M) | Vinegar | Vinegar | Vinegar |
| 5 | Ryllis (VL) | vs. | 12 | Karah (L) | Ryllis | Ryllis | Ryllis |
| 5 | Ryllis (VL) | vs. | 19 | Vinegar (M) | Ryllis | Ryllis | Ryllis |
| 5 | Ryllis (VL) | vs. | 24 | Augusta (H) | Ryllis | Ryllis | Ryllis |
| 12 | Karah (L) | vs. | 19 | Vinegar (M) | Vinegar | Vinegar | Vinegar |
| 12 | Karah (L) | vs. | 24 | Augusta (H) | Karah | Augusta | Karah |
| 19 | Vinegar (M) | vs. | 24 | Augusta (H) | Vinegar | Vinegar | Vinegar |
| 6 | Vic (VL) | vs. | 13 | Kinky (L) | Kinky | Kinky | Kinky |
| 6 | Vic (VL) | vs. | 18 | Mary (M) | Vic | Mary | Mary |
| 6 | Vic (VL) | vs. | 24 | Augusta (H) | Vic | Augusta | Augusta |
| 13 | Kinky (L) | vs. | 18 | Mary (M) | Kinky | Kinky | Kinky |
| 13 | Kinky (L) | vs. | 24 | Augusta (H) | Kinky | Kinky | Kinky |
| 18 | Mary (M) | vs. | 24 | Augusta (H) | Mary | Mary | Mary |
| 14 | Dot (L) | vs. | 16 | Isadore (M) | Dot | Dot | Dot |
| 14 | Dot (L) | vs. | 22 | Dell R. (H) | Dell R. | Dell R. | Dot |
| 16 | Isadore (M) | vs. | 22 | Dell R. (H) | Dell R. | Dell R. | Dell R. |
| 4 | Rena (VL) | vs. | 15 | Evelyn (L) | Rena | Evelyn | Rena |
| 19 | Vinegar (M) | vs. | 15 | Evelyn (L) | Vinegar | Evelyn | Vinegar |
| 22 | Dell R. (H) | vs. | 15 | Evelyn (L) | Dell R. | Dell R. | Dell R. |

Forty-two comparisons were made. The cows fed the lower of the two rations were held in 65, in 57 and in 55 percents of the instances to be on the whole the better nourished and physiologically the more nearly normal. It is the view of the judges that this result gets nowhere. They believe that equally great differences might be found to exist among the animals in any herd fed a uniform ration.

In no one of the various ways in which this problem was attacked in the third examination was anything decidedly indicative discovered tending to show relationship between the protein content of the ration and the continued physical well being of the cows.

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[1] This phraseology should be interpreted to imply that the cow whose name occurs to the left, that is to say, in the left hand column (i. e., 1, Granny) was fed a ration carrying a lower digestible protein content that the ration which was fed to the cow whose name occurs to the right of the pair, that is to say, in the second column (i. e., 8, Ardelle).

## THE 1917 EXAMINATION

The fourth examination was conducted on May 24, 1917, along lines similar to those employed in 1916, special attention being given to general appearance, thickness of skin, quality of hair, surface temperature, color of mucous membranes and judging by pairs, in the latter instance the cattle being placed in line without regard to the ration they had been getting and numbered consecutively. The judges had only a general idea as to the conduct of the experiment and knew nothing whatsoever regarding the individuality of the various cows. The following statement lists the cows and indicates the rations they had received as well as the length of time of feeding.

**Very low protein ration**

| | | | |
|---|---|---|---|
| 1 | Granny .... | 2 years, | 8 months |
| 2 | Katydid ... | 2 " | 8 " |
| 3 | Phoebe .... | 2 " | 8 " |
| 4 | Rena ..... | 2 " | 1 " |
| 5 | Ryllis ..... | 1 " | 11 " |
| 6 | Vic ....... | 2 " | 3 " |
| 7 | Vt. Peony.. | 2 " | 3 " |

**Low protein ration**

| | | | |
|---|---|---|---|
| 9 | Ardelle .... | 10 years, | 10 months |
| 10 | Grace ..... | 10 " | 10 " |
| 11 | Effa ...... | 4 " | 4 " |
| 12 | Karah .... | 2 " | 5 " |
| 13 | Kinky ..... | 2 " | 8 " |

**Medium protein ration**

| | | | |
|---|---|---|---|
| 14 | Isadore .... | 5 years, | 1 month |
| 15 | Lanta 2nd.. | 4 " | 11 " |
| 16 | Mary ..... | 5 " | 1 " |
| 17 | Vinegar ... | 2 " | 2 " |

**High protein ration**

| | | | |
|---|---|---|---|
| 18 | Fizzy ..... | 4 years, | 1 month |
| 19 | Dell R..... | 4 " | 5 " |
| 20 | Nesbit .... | 4 " | 10 " |
| 21 | Augusta ... | 2 " | |

Dot, Evelyn and Lanta (low) and Hepsy (high), appearing in 1916, had been withdrawn or were for other reasons unavailable. The previous methods of data presentation have been followed in the present instance.

### GENERAL APPEARANCE

The three judges were asked to express themselves as to the general appearance of the individual animals, with results which may be concretely expressed as follows:

| Very low | Good | Medium | Poor | Low | Good | Medium | Poor | Medium | Good | Medium | Poor | High | Good | Medium | Poor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granny | 2 | 1 | .. | Ardelle | 2 | .. | 1 | Isadore | .. | 1 | 2 | Augusta | .. | .. | 3 |
| Katydid | 3 | .. | .. | Effa | .. | 3 | .. | Lanta 2nd | 2 | .. | 1 | Dell R. | 1 | 1 | 1 |
| Phoebe | 3 | .. | .. | Grace | .. | 3 | .. | Mary | .. | 2 | 1 | Fizzy | .. | 2 | 1 |
| Rena | 3 | .. | .. | Karah | .. | 2 | 1 | Vinegar | .. | 1 | 2 | Nesbit | 1 | 2 | .. |
| Ryllis | 3 | .. | .. | Kinky | 3 | .. | .. | | | | | | | | |
| Vt. Peony | 1 | 2 | .. | | | | | | | | | | | | |
| Vic | 1 | 2 | .. | | | | | | | | | | | | |
| Total | 16 | 5 | 0 | | 5 | 8 | 2 | | 2 | 4 | 6 | | 2 | 5 | 5 |
| Total % | 76 | 24 | 0 | | 33 | 54 | 13 | | 17 | 33 | 50 | | 17 | 42 | 41 |

Clearly the cows fed the very low protein ration outclassed their competitors and those fed the low protein ration were easily second. The former group was made up of cows distinctly younger than the others; the latter of older cows.

### THICKNESS OF SKIN

The same comparisons as were made in previous examinations were instituted as to the hides, with the following results:

| Very low | Thick | Medium | Thin | Low | Thick | Medium | Thin | Medium | Thick | Medium | Thin | High | Thick | Medium | Thin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granny | .. | 2 | 1 | Ardelle | .. | 1 | 2 | | | | | Augusta | 2 | 1 | .. |
| Katydid | .. | .. | 3 | Effa | 2 | 1 | .. | Isadore | 1 | 1 | 1 | Dell R. | .. | 3 | .. |
| Phoebe | .. | 2 | 1 | Grace | .. | 1 | 2 | Lanta 2nd | 2 | 1 | .. | Fizzy | 3 | .. | .. |
| Rena | .. | 3 | .. | Karah | .. | 3 | .. | Mary | 2 | 1 | .. | Nesbit | 3 | .. | .. |
| Ryllis | .. | 1 | 2 | Kinky | .. | 1 | 2 | Vinegar | 3 | .. | .. | | | | |
| Vt. Peony | .. | 1 | 2 | | | | | | | | | | | | |
| Vic | 2 | 1 | .. | | | | | | | | | | | | |
| Total | 2 | 10 | 9 | | 2 | 7 | 6 | | 8 | 3 | 1 | | 8 | 4 | 0 |
| Total % | 10 | 48 | 42 | | 13 | 47 | 40 | | 66 | 25 | 9 | | 67 | 33 | 0 |

Here again the very low ration excells as compared with the others—so be it a relatively thin skin is desired; and the low ranks next. The cows fed the most protein had the thicker skins and those fed the lesser amounts the thinner skins; and this is just what might be expected physiologically.

### QUALITY OF HAIR

The quality of the hair was studied with results as displayed in the following table:

| | Fine | Medium | Coarse | | Fine | Medium | Coarse | | Fine | Medium | Coarse | | Fine | Medium | Coarse |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Very low | | | | Low | | | | Medium | | | | High | | | |
| Granny | 1 | .. | 2 | Ardelle | 2 | 1 | .. | Isadore | .. | .. | 3 | Augusta | .. | .. | 3 |
| Katydid | 2 | 1 | .. | Effa | .. | 2 | 1 | Lanta 2nd | 1 | 2 | .. | Dell R. | .. | 1 | 2 |
| Phoebe | 1 | 2 | .. | Grace | .. | 2 | 1 | Mary | .. | 2 | 1 | Fizzy | .. | .. | 3 |
| Rena | 3 | .. | .. | Karah | .. | 1 | 2 | Vinegar | .. | .. | 3 | Nesbit | .. | 2 | 1 |
| Ryllis | 1 | 2 | .. | Kinky | 3 | .. | .. | | | | | | | | |
| Vt. Peony | 1 | 2 | .. | | | | | | | | | | | | |
| Vic | 2 | 1 | .. | | | | | | | | | | | | |
| Total | 11 | 8 | 2 | | 5 | 6 | 4 | | 1 | 4 | 7 | | 0 | 3 | 9 |
| Total % | 52 | 38 | 10 | | 33 | 40 | 27 | | 9 | 33 | 58 | | 0 | 25 | 75 |

These results are entirely in accordance with those shown in the last table. The cows fed the lower protein diets proved to be finer haired than those fed the higher protein rations.

## SURFACE TEMPERATURES

Surface temperatures were compared, with the following results:

SURFACE TEMPERATURE

| | Warm | Medium | Cool | | Warm | Medium | Cool | | Warm | Medium | Cool | | Warm | Medium | Cool |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Very low | | | | Low | | | | Medium | | | | High | | | |
| Granny | 2 | 1 | .. | Ardelle | 2 | 1 | .. | Isadore | .. | 1 | 2 | Augusta | .. | .. | 3 |
| Katydid | .. | 3 | .. | Effa | .. | 2 | 1 | Lanta 2nd | .. | 1 | 2 | Dell R. | 1 | 1 | 1 |
| Phoebe | 2 | .. | 1 | Grace | 2 | 1 | .. | Mary | .. | .. | 3 | Fizzy | 1 | 1 | 1 |
| Rena | 1 | 1 | 1 | Karah | 1 | .. | 2 | Vinegar | .. | .. | 3 | Nesbit | .. | 2 | 1 |
| Ryllis | .. | 1 | 2 | Kinky | 2 | 1 | .. | | | | | | | | |
| Vt. Peony | 2 | 1 | .. | | | | | | | | | | | | |
| Vic | 2 | 1 | .. | | | | | | | | | | | | |
| Total | 9 | 8 | 4 | | 7 | 5 | 3 | | 0 | 2 | 10 | | 2 | 4 | 6 |
| Total % | 43 | 38 | 19 | | 47 | 33 | 20 | | 0 | 17 | 83 | | 17 | 37 | 50 |

Clearly the cows fed the less nitrogenous rations showed as a class a somewhat warmer temperature.

## MUCOUS MEMBRANES

The hue of the mucous membranes was considered and the results are appended:

| Very low | Red | Normal | Pale | Low | Red | Normal | Pale | Medium | Red | Normal | Pale | High | Red | Normal | Pale |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granny | .. | 3 | .. | Ardelle | .. | 1 | 2 | Isadore | .. | 3 | .. | Augusta | .. | .. | 3 |
| Katydid | 1 | 2 | .. | Effa | .. | 2 | 1 | Lanta 2nd | .. | 2 | 1 | Dell R. | .. | 1 | 2 |
| Phoebe | 1 | 2 | .. | Grace | 1 | 2 | .. | Mary | .. | 1 | 2 | Fizzy | 1 | 1 | 1 |
| Rena | 1 | 2 | .. | Karah | .. | 1 | 2 | Vinegar | 3 | .. | .. | Nesbit | 3 | .. | .. |
| Ryllis | 3 | .. | .. | Kinky | 1 | 2 | .. | | | | | | | | |
| Vt. Peony | .. | 1 | 2 | | | | | | | | | | | | |
| Vic | .. | 2 | .. | | | | | | | | | | | | |
| Total | 7 | 12 | 2 | | 2 | 8 | 5 | | 3 | 6 | 3 | | 4 | 2 | 6 |
| Total % | 33 | 57 | 10 | | 13 | 54 | 33 | | 25 | 50 | 25 | | 33 | 17 | 50 |

The proportion of non-normality—the writer hardly feels justified in using the word abnormality—tends to increase towards the right of the table. Clearly very low protein consumption has not injuriously affected the mucous membranes.

### PAIRING

The cows were brought out in pairs as in previous examinations and the judges were asked to select in each instance the animal thought to be in the better state of nutrition, and at the same time to express their opinions as to the rations fed to each. The following tabular statement sets forth the results as to judgment in respect to the physical condition of the animals, the guess—if we may call it such—as to which cow was fed which ration and a statement as to accuracy of the guess.

| The Pairs | | | | Judge I | Judge II | Judge III |
|---|---|---|---|---|---|---|
| Name and ration | Age | Name and ration | Age | Choices | Choices | Choices |
| Granny (VL) | 6 | Isadore (M) | 10 | Granny ...L | Granny ...L | Granny ..H |
| Vt. Peony (VL) | 9 | Augusta (H) | 11 | Vt. Peony.L | Vt. Peony.L | Vt. Peony.H |
| Phoebe (VL) | 8 | Mary (M) | 9 | Phoebe ...L | Phoebe ...L | Phoebe ...L |
| Rena (VL) | 7 | Dell R. (H) | 8 | Rena .....L | Rena .....L | Rena ....H |
| Katydid (VL) | 7 | Lanta 2nd (M) | 9 | No choice .. | Katydid ..L | Lanta 2nd H |
| Kinky (L) | 7 | Dell R. (H) | 8 | Kinky ....L | Kinky ....L | Kinky ....L |
| Ardelle (L) | 14 | Augusta (H) | 11 | Ardelle ...L | Ardelle ...L | Ardelle ..H |
| Katydid (VL) | 7 | Augusta (H) | 11 | Katydid ..L | Katydid ..L | Katydid ..L |
| Rena (VL) | 7 | Vinegar (M) | 8 | Rena .....L | Rena .....L | Rena ....H |
| Ryllis (VL) | 10 | Nesbit (H) | 9 | Ryllis ....L | Ryllis ....L | Ryllis ....H |
| Karah (L) | 7 | Isadore (M) | 10 | Isadore ...L | Karah ....L | Karah ...H |
| Grace (L) | 14 | Vinegar (M) | 8 | Grace ....L | Grace ....L | Grace ....H |
| Karah (L) | 7 | Dell R. (H) | 8 | Dell R. ...L | Karah ....L | Karah ...H |
| Vic (VL) | 7 | Mary (M) | 9 | Vic ......L | Vic ......L | Mary .....L |
| Grace (L) | 14 | Mary (M) | 9 | Grace ....L | Grace ....L | Grace ....H |
| Vt. Peony (VL) | 9 | Nesbit (H) | 9 | Vt. Peony.L | Vt. Peony.L | Vt. Peony.H |
| Effa (L) | 9 | Isadore (M) | 10 | Effa ......L | Effa ......L | Effa ......L |
| Vic (VL) | 7 | Dell R. (H) | 8 | Vic ......L | Vic ......L | Vic ......H |
| Vic (VL) | 7 | Augusta (H) | 11 | Vic ......L | Vic ......L | Vic ......H |

It will be noted that in 15 of the 19 comparisons the judges were a unit in their placings as to the relative physical conditions of the animals and that divergencies occurred only in four cases. It should be said that in several instances the choices were hard to make. However, when it came to expressing opinions as to the relationships between the nature of the rations and the individual animals, the judges varied. Judge II, without a single failure, laid his hand on the cow fed the lower of the two protein rations and said it was the better nourished animal. Judge I made two mistakes, and in one case said that the differences, if any, were too slight to enable him to hazard an estimate. In 16 cases he declared that the cow fed the lower protein ration was the better nourished of the two animals. Judge III, on the other hand, made 14 mistakes; that is to say, while chosing the better nourished animal in 17 of the 19 instances, he gave it as his judgment that his choices had been fed the narrower rations whereas the contrary was the fact in 14 instances. Rephrasing this statement in another manner, it may be said that judges I and II agreed as to which were the better nourished animals and felt in a general way that if any relationship whatsoever existed between the nature of the ration fed and the physical well-being of the animals, the cows fed the low or the very low protein rations were, as judged by superficial examination, the better for it as compared with those fed narrower rations. On the contrary, judge III, making the same choices as did his associates, was quite at sea in his estimates as to the manner of the feeding.

The age factor should not be overlooked. Fourteen of the 19 cows fed the lower protein ration were younger than those with which they were paired, the difference in age averaging two years. In only three cases were the cows whose names appear in the left hand column of the table materially older than their competitors. They were, however, their years to the contrary notwithstanding, deemed to be better animals than their pairmates.

However, the outstanding feature of this particular trial is this, that these three expert men, whose lifework has been given over to the study of cattle and cattle feeding, did not find that the physical well-being of the cows had been injured in any respect by long continued feeding on low protein rations, extending in two cases for more than ten years, or by three years of continuous feeding on very low protein rations. Surely this is a significant outcome.

### THE 1918 EXAMINATION

The fifth physical examination was conducted on May 27, 1918, along lines similar to those employed in the third and fourth surveys, particular attention being paid to the general appearance, to the thickness of the skin and to the quality of the hair. Two of the five judges had not heretofore surveyed the herd; the other three had looked it over once or twice previously, one of them (Story) being acquainted with the animals and their feeding.

The following statement lists the cows and indicates the rations they had received as well as the length of time of feeding the ration in question at the time when the examination was made in late May, 1918.

Very low protein ration

| | | |
|---|---|---|
| Katydid | 3 years, | 8 months |
| Rena | 3 " | 1 " |
| Ryllis | 2 " | 11 " |
| Vic | 3 " | 3 " |
| Vt. Peony | 3 " | 3 " |
| Catrina 2nd | 3 " | 3 " |

Low protein ration

| | | |
|---|---|---|
| Karah | 3 years, | 5 months |

Medium protein ration

| | | |
|---|---|---|
| Isadore | 6 years, | 2 months |

High protein ration

| | | |
|---|---|---|
| Fizzy | 5 years, | 1 month |
| Nesbit | 4 " | 10 " |
| Augusta | 3 " | |

Since the 1917 survey was made a large share of the cows then at work for one reason and another had been withdrawn, as set forth below:

*Very low protein ration.* Granny, off trial 1918, barren; Phoebe, sold June 24, 1917, barren.

*Low protein ration.* Ardelle, sold February 6, 1918, age; Grace, sold May 24, 1918, age, barren; Effa, sold July 24, 1917, barren; Kinky, sold February 1, 1918, barren.

*Medium protein ration.* Lanta 2nd, sold July 24, 1917; Mary, sold July 24, 1917, barren; Vinegar, died January 29.

*High protein ration.* Dell R., sold August 3, 1917, barren.

### GENERAL APPEARANCE

The five judges were asked to express themselves as to the general appearance of the individual animals. Each worked independently, with the results which may be stated in condensed form as follows:

| Very low | Good | Medium | Poor |
|---|---|---|---|
| Katydid | 1 | 4 | .. |
| Rena | 4 | 1 | .. |
| Ryllis | 4 | 1 | .. |
| Vic | 4 | .. | 1 |
| Vt. Peony | .. | 4 | 1 |
| Catrina 2nd | 1 | 4 | .. |
| Total | 14 | 14 | 2 |
| Total % | 47 | 47 | 5 |

| Low | Good | Medium | Poor |
|---|---|---|---|
| Karah | 1 | 2 | 2 |
| % | 20 | 40 | 40 |

| Medium | Good | Medium | Poor |
|---|---|---|---|
| Isadore | 1 | 2 | 2 |
| % | 20 | 40 | 40 |

| High | Good | Medium | Poor |
|---|---|---|---|
| Fizzy | 1 | 2 | 2 |
| Nesbit | .. | 1 | 4 |
| Augusta | .. | 1 | 4 |
| Total | 1 | 4 | 10 |
| Total % | 6 | 27 | 67 |

The results afforded by the few remaining cows are striking. The very low protein fed cows looked better than those fed the highly proteinous ration. This outcome is in line with that secured in the previous survey. It should be remembered again that the very low protein fed group were younger cows than their competitors.

### THICKNESS OF SKIN

Comparisons similar to those made in previous examinations were instituted as to the thickness of the hides, with results as follows:

| Very low | Thick | Medium | Thin |
|---|---|---|---|
| Katydid | .. | 4 | 1 |
| Rena | .. | 4 | 1 |
| Ryllis | .. | 2 | 3 |
| Vic | 1 | 1 | 3 |
| Vt. Peony | 2 | 3 | .. |
| Catrina 2nd | .. | .. | 5 |
| Total | 3 | 14 | 13 |
| Total % | 10 | 47 | 43 |

| Low | Thick | Medium | Thin |
|---|---|---|---|
| Karah | 1 | 4 | .. |
| % | 20 | 80 | .. |

| Medium | Thick | Medium | Thin |
|---|---|---|---|
| Isadore | .. | 3 | 2 |
| % | .. | 60 | 40 |

| High | Thick | Medium | Thin |
|---|---|---|---|
| Fizzy | 2 | 3 | .. |
| Nesbit | 5 | .. | .. |
| Augusta | 3 | 2 | .. |
| Total | 10 | 5 | .. |
| Total % | 67 | 33 | .. |

The cows fed the less proteinous rations possessed the thinner skins and those fed the higher rations the thicker ones—as might be expected.

### QUALITY OF HAIR

The quality of the hair of the animals was studied with results described in the following table:

| | Fine | Medium | Coarse | | Fine | Medium | Coarse | | Fine | Medium | Coarse |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Very low | | | | Low | | | | High | | | |
| Katydid | 3 | 1 | 1 | Karah | .. | 4 | 1 | Fizzy | 2 | 3 | .. |
| Rena | 3 | 2 | .. | | — | — | — | Nesbit | 1 | 2 | 2 |
| Ryllis | 1 | 4 | .. | % | .. | 80 | 20 | Augusta | .. | 2 | 3 |
| Vic | 4 | 1 | .. | | | | | | | | |
| Vt. Peony | 2 | 2 | 1 | | | | | | | | |
| Catrina 2nd | 4 | 1 | .. | Medium | | | | | | | |
| | — | — | — | Isadore | .. | 2 | 3 | | — | — | — |
| Total | 17 | 11 | 2 | | — | — | — | Total | 3 | 7 | 5 |
| Total % | 57 | 37 | 6 | % | .. | 40 | 60 | Total % | 20 | 47 | 33 |

The outcome is quite in accordance with that shown in the preceding table, the cows fed the lower protein rations being finer haired than their competitors.

### COMPARISONS

When it came to the attempting to say what ration was fed to what cow, the judges were much at sea. One of them (Story) stood on the sidelines. The record was as follows:

| | Correct | Next to correct | Wrong |
|---|---|---|---|
| A | 8 | 3 | .. |
| B | 3 | 1 | 7 |
| C | 5 | 3 | 3 |
| D | 2 | 3 | 6 |

Judges A and C had a pretty close notion as to who's who and what's what, whereas judges B and D were far at sea. All four were good judges of dairy cattle, but the members of the former group were probably somewhat better informed than were their associates in matters of animal nutrition. The fact that so many of the low and medium protein ration cows had dropped out during the year rendered it impossible to make comparisons by pairs which had heretofore been instituted.

Two of the judges expressed themselves in writing as follows:

"It is difficult to draw conclusions from the results of this 1918 survey as to whether or not cows fed very low amounts of protein for several years will always remain in as fine a condition as do the cows thus fed in this trial. However, it is certain that the cows which appeared to the best advantage and seemed in the best physical condition in the 1916, 1917 and 1918 surveys, were those which were fed relatively small amounts of protein. In view of this fact, are we not warranted in drawing the conclusion that there must be something to the belief which is becoming increasingly prevalent among careful students of animal nutrition, that the long continued use of high protein rations is almost always certain to cause cows to become unthrifty?

I feel that it would be of little value longer to continue this trial. Some of the cows which have been fed the very low protein ration for more than three and a half years show no evidence of breaking down, although losing somewhat in weight."

"A marked difference was observed in the general condition of these cows, several remaining in good shape and retaining their vitality, health and productivity, whereas others have become barren and unproductive. The writer, having had some experience in feeding high protein rations to dairy cows and noting the results, was especially interested to observe that the cows used in this prolonged trial reacted in much the same manner as did those which he has had the opportunity of having under observation elsewhere. In his judgment, the use of high protein rations tends, almost without exception, to induce a breaking down of the reproductive system and, as a result, to bring about a complete change in the general appearance of the cow. Cows thus fed become staggy in their appearance and unproductive, whereas cows fed a ration carrying a lower protein content, have, as a rule, retained their strength, vigor and productivity for long periods.

The writer believes that it is quite evident that less protein can be fed to advantage than has been advocated in the past and the dairy herd kept for a longer period in good physical condition."

The upshot of this final survey was that, aside from the fact that the cows fed the very low protein ration for several years were somewhat more spare in flesh as a result, the bodily vigor and serviceability of the animals did not seem to be affected. This observation, it may be remarked parenthetically, is quite in line with those made in the warring countries in connection with the bodily well-being of their populations fed on a less proteinous diet than was usually eaten before the battle flags were unfurled.

## THE 1919 EXAMINATION

Under date of July 31, 1919, the station animal husbandman, after having carefully examined the cows, reported as follows:

*Vermont Peony.*—Continued on very low protein ration 53 months; 7-11 years old; coat somewhat harsh; condition fair.

*Ryllis.*—Continued on very low protein ration 48 months; 8-12 years old; coat somewhat harsh; condition fair.

*Katydid.*—Continued on very low protein ration 56 months; 5-9 years old; coat harsh and tight; condition quite thin.

*Vermont Una 2nd.*—Continued on very low protein ration 41 months; 3-7 years old; coat somewhat harsh; condition somewhat thin but not unthrifty.

*Rena* and *Vic.*—Respectively fed continuously for 50 and 52 months on the very low protein rations were dropped from the trial in early June and through inadvertence were not examined. They were in good condition in May, 1918.

*Alice.*—Fed alternately by lactations the low and the very low protein rations during 53 months; 4-8 years old; coat fair; condition good.

He stated further that no evidence of poor nutrition or unthriftiness was visible, with the possible exception of Katydid, who was quite thin; and that in general appearance, condition and quality these cows might have been mixed with the regular University Farm herd without lowering its general average of appearance. In this connection it should be remembered that every other cow in the herd ate more digestible protein daily than did the five animals above mentioned.

Ryllis, Vermont Una 2nd and Alice were kept on a somewhat low protein diet for two years longer.

Ryllis gave approximately 2,700 pounds of milk and 160 pounds of fat during the next eight months, when she went dry. Calving again in September, 1920, she gave about 12 pounds of milk and 0.8 pounds of fat daily for a dozen or more weeks. She showed no further signs of going down hill physically, despite five and a half years of continued feeding on the low protein rations. She was killed in 1921, following a tuberculin test.

Vermont Una 2nd gave about 3,000 pounds of milk and about 160 pounds of fat during the next eight months, when she went dry. Calving again in June she gave about 1,400 pounds of milk and about 75 pounds of fat during the next five months. She showed no evidence of further deterioration as a result of five years of continued feeding on low protein rations. She was in good condition in the spring of 1922.

Alice gave a rather small milk flow at the close of her test but calved late in the following November and during the ensuing 12 months on a low protein diet gave 4284 pounds of milk and about 235 pounds of fat. She was continued on a similar diet and is now—spring of 1922—in good physical condition.

## GENERAL SUMMARY OF STUDY OF PHYSICAL EFFECTS

### GENERAL APPEARANCE

II.[1] "The cows eating daily for eight years a medium protein ration possibly appeared to better advantage than those fed a lower protein ration. (but) this tendency was neither distinct nor conclusive."

III. "There does not seem to be any pronounced effect which justly may be ascribed to the nature of the feeding."

IV. "The cows fed the very low protein ration (for three years) outclassed their competitors and those fed the low protein ration were easily second. The former group was made up of cows which were distinctly younger than the others: the latter of the older cows."

V. The very low protein fed cows looked better than those fed low and medium amounts and the latter better than those fed the highly proteinous rations. (The former) were younger cows than their competitors.

### THICKNESS OF SKIN

I. "Nothing positive can be said as to the results."

II. "The result is certainly not conclusive enough to warrant dogmatic assertion as to correlation."

III. "The hides of the cows which were fed the larger amounts of protein tended to be somewhat thicker than those fed the lesser amounts."

IV. "The cows fed the most protein had the thicker skins and those fed the lesser amounts the thinner skins."

V. "The cows fed the less proteinous rations possessed the thinner skins and those fed the higher rations the thicker ones."

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[1] The Roman numerals I to V refer to the several physical examinations of 1913, 1914, 1916, 1917 and 1918, respectively, as set forth on pages 70 to 96. The statements in this general summary on the two pages following are quotations from the longer statements previously made in the full discussion, slightly varied as to their phraseology in some cases for purposes of condensation; hence the quotation marks and hence the parentheses.

### QUALITY OF HAIR

I. "No pronounced and positive outcome can be declared."

II. "No correlation appears."

III. "Heavy feeding with protein does not necessarily produce a finer quality of hair (nor does) a low protein ration necessarily produce coarse hair."

IV. "The cows fed the lower protein diets proved to be finer haired than those fed the higher protein rations."

V. "The cows fed the lower protein rations (were) finer haired then their competitors."

### MUCOUS MEMBRANES

I. "Little light can be gained from the study of the mucous membrane figures."

II. "No correlation appears."

III. "The cows getting the lower protein rations as a whole had highly colored mucous membranes," whereas the reverse was true of those fed the narrower rations. Herd infection with granular vaginitis renders the observation of little worth.

IV. "Clearly very low protein consumption has not injuriously affected the mucous membrane."

### SURFACE TEMPERATURES

III. "The cows fed the very wide ration were relatively a warm bunch and those fed the narrow one relatively a cool proposition."

IV. "Clearly the cows fed the less nitrogenous rations showed as a class a somewhat warmer temperature."

### DIRECT COMPARISONS

II. A little less than one-half the guesses as to which was which were correct, and 30 percent were wrong.

III. "It is the view of the judges that (the) result gets nowhere."

IV. Two judges guessed in the main correctly, one incorrectly, and all three agreed as to the relative physical condition of the several cows.

V. "Judges A and C had a pretty close notion as to who's who and what's what, whereas judges B and D were far at sea."

### IN GENERAL

I. "The results lead nowhere." "Neither those cows fed high nor those fed low protein rations seemed to have suffered physically as a result" (1913; after 6½ years' feeding).

II. "Variations in protein rationing were not important factors in the maintenance of the physical condition of the cows" (1914; after 8 years' feeding).

III. Nothing "decidedly indicative (was) discovered tending to show relationship between the protein content of the ration and the continued physical well being of the cows" (1916; after—in some cases—9½ years' feeding).

IV. "Experts (could) not find that the physical well being of the cows had been injured by long continued feeding on low protein rations, extending in two cases for more than 10 years, or by three years of continuous feeding on very low protein rations" (1917).

V. "The upshot of the final survey was that, aside from the fact that the cows fed the very low protein ration for several years were somewhat more spare in flesh as a result, their bodily vigor and serviceability did not seem to be affected" (1918).

These results, secured after feeding for a long series of years, naturally lead one to query whether wide rations may not be fed to advantage whenever protein concentrates for any reason rule especially high in price, or to dry stock, or under any conditions whatsover when economy in feed purchase is a vital factor. Certain it is if the results secured in this long drawn out trial, which the writer believes is one of the most if not the most extensive feeding trial with milch cows ever carried out at any Station, are applicable to feeding practice elsewhere, and he firmly believes that they are, it is safe to assume that no ill effects would be likely to follow the prolonged use of far wider rations than commonly have been advised.

### (*c*) UPON THE LIVE WEIGHTS

Was any tendency manifest in favor of either of the rations to increase the weight of the cows? Weights were taken consistently for three successive days every four weeks. The usual changes occurred, the younger cows increasing somewhat in weight as they became mature, the pregnant animals increasing as calving approached and decreasing after calving. A careful study and comparison of the large number of weights has resulted in the following tabular statement, which shows as nearly as may be the average weights of each cow during each milking period. The weights when the cows were dry and nearly ready to calve were excluded in making up the averages. The animals are grouped according to their locations in the trials. Each weight represents a lactation average.

It should be said that the records of the mature cows only were used in the comparisons cited in this discussion, whether located in the long continued or the short alternation trials. Of course the young animals gained regardless of their ration, the summation being:

To lower from high, 106 gains, 10 losses, 20 unchanged.

To higher from lower, 104 gains, 6 losses, 18 unchanged.

The live weights of the cows fed in the short alternation trials are not printed. Half of the cows were young animals, increasing in weight regardless of ration changes.

LIVE WEIGHTS (AVERAGES IN EACH CASE FOR A SINGLE LACTATION)

| | I | | II | | III | | IV | | V | | VI | | VII | | VIII | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. |
| LONG CONTINUOUS FEEDING—LOW PROTEIN RATION | | | | | | | | | | | | | | | | |
| Aggie ....... | 8 | 909 | 10 | 914 | 12 | 896 | 14 | 813 | | | | | | | | |
| Ardelle ...... | 4 | 683 | 5 | 746 | 6 | 775 | 7 | 773 | 8 | 813 | 9 | 801 | 10 | 799 | 11 | 800 |
| Aster ........ | 3 | 560 | 4 | 716 | 5 | 819 | 6 | 889 | 7 | 883 | 8 | 899 | | | | |
| Fyra ........ | 5 | 1085 | 7 | 1107 | 8 | 1115 | 9 | 1117 | 10 | 1152 | 11 | 1123 | | | | |
| Grace ....... | 4 | 875 | 5 | 905 | 6 | 964 | 7 | 948 | 8 | 965 | 9 | 971 | 10 | 972 | 11 | 918 |
| Mab ......... | 3 | 650 | 4 | 858 | 5 | 899 | 6 | 899 | 7 | 896 | 8 | 908 | 9 | 872 | 10 | 899 |
| Sheila ....... | 5 | 782 | 6 | 838 | 7 | 858 | 8 | 845 | 9 | 861 | 10 | 870 | 11 | 842 | 12 | 815 |
| Kinky ....... | 4 | 773 | 5 | 867 | 7 | 773 | | | | | | | | | | |
| LONG CONTINUOUS FEEDING—MEDIUM PROTEIN RATION | | | | | | | | | | | | | | | | |
| Angie ....... | 5 | 855 | 5 | 925 | 6 | 1039 | 7 | 1037 | 8 | 1040 | 9 | 1017 | 10 | 1060 | | |
| Elbaje ....... | 6 | 1160 | 7 | 1237 | 9 | 1250 | 10 | 1227 | 11 | 1206 | | | | | | |
| Isadore ...... | 6 | 910 | 7 | 886 | 8 | 872 | | | | | | | | | | |
| Karah ....... | 4 | 824 | 5 | 838 | | | | | | | | | | | | |
| L. Hexham... | 7 | 962 | 8 | 971 | 9 | 1039 | 11 | 1018 | 12 | 989 | | | | | | |
| Mattie ....... | 3 | 675 | 4 | 747 | 5 | 825 | 6 | 856 | | | | | | | | |
| Mu .......... | 7 | 892 | 8 | 852 | | | | | | | | | | | | |
| Rocket ...... | 3 | 791 | 4 | 885 | 5 | 988 | 6 | 1097 | 7 | 1089 | 8 | 1117 | 9 | 1107 | | |
| Ryllis ....... | 5 | 813 | 6 | 824 | 7 | 840 | | | | | | | | | | |
| Slicker ...... | 9 | 893 | 10 | 913 | 11 | 922 | 12 | 930 | 13 | 930 | | | | | | |
| Vt. Ivis...... | 5 | 803 | 6 | 841 | | | | | | | | | | | | |
| Vt. Una ...... | 8 | 827 | 9 | 896 | 10 | 848 | 11 | 842 | 12 | 832 | | | | | | |

|  | I |  | II |  | III |  | IV |  | V |  | VI |  | VII |  | VIII |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. |
| LONG CONTINUOUS FEEDING—HIGH PROTEIN RATION |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cassandra ... | 6 | 836 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Catrina ...... | 6 | 1044 | 7 | 1067 | 8 | 1110 |  |  |  |  |  |  |  |  |  |  |
| Cloedah ..... | 5 | 960 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Electa ....... | 4 | 829 | 5 | 837 |  |  |  |  |  |  |  |  |  |  |  |  |
| Fizzy ........ | 4 | 873 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hepsy ....... | 6 | 926 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hilda ....... | 6 | 905 | 7 | 938 | 9 | 960 |  |  |  |  |  |  |  |  |  |  |
| Madam ...... | 3 | 658 | 4 | 770 | 5 | 866 | 6 | 916 | 7 | 919 |  |  |  |  |  |  |
| Peggy ....... | 3 | 706 | 4 | 807 | 5 | 799 | 6 | 837 |  |  |  |  |  |  |  |  |
| Phoebe ...... | 3 | 960 | 4 | 1030 | 5 | 1033 |  |  |  |  |  |  |  |  |  |  |
| Rosel ........ | 11 | 1040 | 13 | 1060 | 14 | 993 | 16 | 998 |  |  |  |  |  |  |  |  |
| Vt. Peony.... | 5 | 821 | 6 | 833 |  |  |  |  |  |  |  |  |  |  |  |  |
| Vic .......... | 11 | 802 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Yuba ........ | 8 | 1043 | 9 | 1028 | 10 | 1047 | 11 | 1036 | 12 | 1081 | 13 | 1028 |  |  |  |  |
| Zeta ......... | 8 | 858 | 9 | 860 | 10 | 833 | 11 | 835 | 13 | 823 | 14 | 825 |  |  |  |  |
| LONG CONTINUOUS FEEDING—VERY LOW PROTEIN RATIONS |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Granny ...... | 4 | 963 | 5 | 902 |  |  |  |  |  |  |  |  |  |  |  |  |
| Katydid ..... | 5 | 830 | 6 | 810 | 7 | 772 | 8 | 753 | 9 | 712 | (2 mos.) |  |  |  |  |  |
| Phoebe ...... | 6 | 1034 | 7 | 995 |  |  |  |  |  |  |  |  |  |  |  |  |
| Rena ........ | 4 | 789 | 5 | 747 | 6 | 762 | 7 | 750 | 8 | 744 | (2 mos.) |  |  |  |  |  |
| Ryllis ....... | 8 | 852 | 9 | 862 | 10 | 816 | 11 | 795 |  |  |  |  |  |  |  |  |
| Vt. Peony .... | 7 | 841 | 8 | 799 | 9 | 812 | 10 | 796 |  |  |  |  |  |  |  |  |
| Vic .......... | 5 | 837 | 6 | 806 | 7 | 800 | 8 | 813 |  |  |  |  |  |  |  |  |
| LACTATION ALTERNATION FEEDING—LOW AND MEDIUM PROTEIN RATIONS |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Low |  | Medium |  | Low |  | Medium |  | Low |  | Medium |  | Low |  | Medium |  |
| Crystal ...... | 5 | 788 | 6 | 830 | 7 | 851 | 8 | 872 | 9 | 800 | 10 | 857 | 11 | 859 | 12 | 837 |
| Elizabeth .... | 7 | 841 | 8 | 830 | 9 | 877 | 10 | 862 | 11 | 890 | 12 | 860 | 13 | 864 | 14 | 837 |
| Zillah ....... | 5 | 943 | 6 | 944 | 7 | 975 | 8 | 970 | 10 | 983 | 11 | 1000 | 12 | 1006 |  |  |
|  | Medium |  | Low |  | Medium |  | Low |  | Medium |  | Low |  | Medium |  | Low |  |
| Edith ....... | 10 | 899 | 12 | 926 | 13 | 899 |  |  |  |  |  |  |  |  |  |  |
| Goldfinch .... | 6 | 832 | 7 | 846 | 9 | 885 | 10 | 917 |  |  |  |  |  |  |  |  |
| Ladybird .... | 7 | 923 | 8 | 972 | 9 | 987 | 10 | 953 | 11 | 950 | 12 | 940 | 13 | 937 |  |  |
| Laura B ..... | 5 | 863 | 6 | 857 |  |  |  |  |  |  |  |  |  |  |  |  |
| Theta ....... | 5 | 771 | 6 | 764 |  |  |  |  |  |  |  |  |  |  |  |  |
| LACTATION ALTERNATION FEEDING—LOW AND HIGH PROTEIN RATIONS |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Low |  | High |  | Low |  | High |  | Low |  | High |  | Low |  | High |  |
| Alta ......... | 10 | 880 | 11 | 864 | 12 | 913 | 13 | 885 | 15 | 909 |  |  |  |  |  |  |
| Cherry ...... | 7 | 843 | 9 | 879 | 10 | 932 | 11 | 897 | 12 | 912 | 13 | 921 | 14 | 900 |  |  |
| Lena ........ | 4 | 808 | 5 | 835 | 7 | 859 | 8 | 860 |  |  |  |  |  |  |  |  |
| Vie .......... | 6 | 867 | 7 | 954 | 8 | 972 | 9 | 969 | 10 | 981 | 11 | 980 |  |  |  |  |
| Dot ......... | 4 | 900 | 5 | 902 | 6 | 932 | 7 | 948 |  |  |  |  |  |  |  |  |
|  | High |  | Low |  | High |  | Low |  | High |  | Low |  | High |  | Low |  |
| Dewdrop .... | 7 | 824 | 8 | 838 | 9 | 886 | 11 | 836 | 12 | 785 | 13 | 801 | 14 | 817 |  |  |
| Hester ..... | 6 | 860 | 7 | 896 | 9 | 940 | 10 | 910 |  |  |  |  |  |  |  |  |
| Kate ....... | 7 | 806 | 8 | 800 | 9 | 866 | 10 | 849 | 11 | 886 | 12 | 874 | 13 | 837 | 14 | 82 |
| Monetta ..... | 6 | 872 | 7 | 809 |  |  |  |  |  |  |  |  |  |  |  |  |
| Santa Rosa... | 8 | 917 | 9 | 924 | 10 | 939 | 11 | 949 | 12 | 966 | 13 | 976 |  |  |  |  |

|  | I |  | II |  | III |  | IV |  | V |  | VI |  | VII |  | VIII |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. | Age | Wt. |
| LACTATION ALTERNATION FEEDING—MEDIUM AND HIGH PROTEIN RATIONS |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Medium |  | High |  | Medium |  | High |  | Medium |  | High |  | Medium |  | High |  |
| Avis | 7 | 799 | 8 | 820 | 10 | 818 | 11 | 807 | 12 | 837 | 13 | 837 | 14 | 831 |  |  |
| Augusta | 4 | 793 | 5 | 784 | 6 | 810 | 7 | 818 | 8 | 830 |  |  |  |  |  |  |
| Fatima | 5 | 939 | 8 | 944 |  |  |  |  |  |  |  |  |  |  |  |  |
| Tansy | 4 | 844 | 5 | 883 | 6 | 935 | 7 | 896 | 8 | 953 | 9 | 948 | 10 | 907 |  |  |
| Vinegar | 4 | 837 | 5 | 862 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | High |  | Medium |  | High |  | Medium |  | High |  | Medium |  | High |  | Medium |  |
| Doris | 6 | 856 | 7 | 895 | 9 | 932 | 10 | 913 | 11 | 939 | 12 | 967 | 13 | 951 |  |  |
| Mildred | 4 | 732 | 5 | 805 | 6 | 861 | 7 | 856 | 8 | 870 | 9 | 863 | 10 | 807 |  |  |
| Perusia Lady | 3 | 812 | 4 | 874 |  |  |  |  |  |  |  |  |  |  |  |  |
| LACTATION ALTERNATION FEEDING—VERY LOW AND LOW PROTEIN RATIONS |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Very low |  | Low |  | Very low |  | Low |  |  |  |  |  |  |  |  |  |
| Alice | 5 | 856 | 6 | 790 | 7 | 789 | 8 | 792 |  |  |  |  |  |  |  |  |
|  | Very low |  | Low |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cherry | 15 | 900 | 16 | 811 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Very low |  | Very low |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Janet | 5 | 848 | 6 | 822 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Low |  | Very low |  | Very low |  | Very low |  | Very low |  |  |  |  |  |  |  |
| Vt. Una 2nd | 3 | 788 | 4 | 761 | 5 | 742 | 6 | 733 |  |  |  |  |  |  |  |  |
|  | Very low |  | Low |  | Low |  | Very low |  | Low |  |  |  |  |  |  |  |
| Catrina 2nd | 6 | 915 | 7 | 900 | 8 | 923 | 9 | 910 | 10 | 917 |  |  |  |  |  |  |
|  | Low |  | Low |  | Very low |  |  |  |  |  |  |  |  |  |  |  |
| Laura B | 8 | 868 | 9 | 840 | 11 | 770 |  |  |  |  |  |  |  |  |  |  |
|  | Very low |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Monetta | 10 | 835 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Very low |  | Low |  | Low |  |  |  |  |  |  |  |  |  |  |  |
| Theta | 7 | 797 | 8 | 729 | 9 | 745 |  |  |  |  |  |  |  |  |  |  |

## LONG CONTINUOUS FEEDING ON A SINGLE RATION

What was the effect of long continued feeding on a very low, a low, a medium or a high protein diet? Postponing for the time being the consideration of the results secured with the very low protein ration, it may be said that the cows fed a low protein diet tended to increase in weight until nine years of age, slightly to fall off in weight when ten years old and decidedly during the following year. The cows fed a medium protein diet similarly increased in weight until their ninth year, fell off a little in the tenth year and a little more in the eleventh. The cows fed a high protein diet lost in weight from their seventh year onwards, save as indicated by the sharp peak in the eleventh year, due to the abnormally high live weight of one cow from January to May, 1912. Apparently a low protein ration fed for several years did not induce loss, but, rather, a gain in live weight; and such loss as occurred after the cows were nine years of age was not greater than that of cows fed medium and high protein rations for equally long periods.

### LACTATION ALTERNATION FEEDING

What are the results when rations differing in their protein contents are fed in alternating lactations? Excluding all records made when the cows were below six years of age and comparing in two ways, namely, averaging lactation averages throughout the life of each cow on the trial for each ration, and comparing a lactation average with that of the previous lactation, the following showing is made:

1. Nine cows; alternating lactations low to high protein ration and back again. Larger weight on high protein ration, 2; on low protein, 3; no difference, 4.

Eight cows; alternating lactations low to medium protein ration and back again. Larger weight on medium protein, 4; on low protein, 4.

Five cows; alternating lactations medium to high protein ration and back again. Larger weight on high protein, 1; on medium protein, 2; no difference, 2.

Summary. Increased live weight on the wider ration, 9; on the narrower ration, 7; indeterminate, 6.

2. When changing from a low protein to a high protein ration. Gains in weight, 10; losses in weight, 5; no change, 3.

When changing from a high protein to a low protein ration. Gains in weight, 12; losses in weight, 8.

When changing from a low protein to a medium protein ration. Gains in weight, 5; losses in weight, 8; no change, 2.

When changing from a medium protein to a low protein ration. Gains in weight, 10; losses in weight, 4; no change, 2.

When changing from a medium protein to a high protein ration. Gains in weight, 5; losses in weight, 4; no change, 2.

When changing from a high protein to a medium protein ration. Gains in weight, 5; losses in weight, 5; no change, 1.

Summary. Increased live weights on changing to the wider ration, 27; lessened live weights on changing to the wider ration, 17; no change 3. Increased live weights on changing to the narrower ration, 20; lessened live weights on changing to the narrower ration, 17; no change, 7.

Either way the data are viewed the wider ration on the whole seems to be somewhat the better and the narrower ration somewhat the poorer live-weight maker.

### SHORT PERIOD ALTERNATION FEEDING

What results were secured with the mature cows used in the short alternation tests?[1] The results may be summarized as follows:

When fed a low protein following a high protein ration. Gains in weight, 15; losses in weight, 29; no change, 11.

When fed a high protein following a low protein ration. Gains in weight, 31; losses in weight, 21; no change, 2.

When fed a low protein following a medium protein ration. Gains in weight, 13; losses in weight, 10; no change, 2.

When fed a medium protein following a low protein ration. Gains in weight, 12; losses in weight, 7; no change, 6.

When fed a medium protein following a high protein ration. Gains in weight, 6; losses in weight, 7; no change, 6.

When fed a high protein following a medium protein ration. Gains in weight, 7; losses in weight, 12; no change, 2.

Summary. When changed to a lower from a higher protein ration. Gains in weight, 34; losses in weight, 46; no change, 19.

When changed to a higher from a lower protein ration. Gains in weight, 50; losses in weight, 40; no change, 10.

There is no majority either way; for 34 plus 19 is greater than 46, 46 plus 19 greater than 34, 40 plus 10 is equal to 50 and 50 plus 10 greater than 40. The outcome is somewhat indeterminate, as might well be expected. Yet it is significant that the larger figures in each case are related to that ration which carries the lower protein content. Thus, in 50 percent of the instances the cows increased in weight in passing from the ration carrying the higher to that carrying the lower digestible protein content, whereas in only 40 percent of the instances did they lose in weight. Similarly, in passing from the ration carrying the lower to that carrying the higher digestible protein content, in 47 percent of the instances, the cows lost in weight, whereas in only 35 percent did they gain in weight.

### VERY LOW PROTEIN FEEDING

Now while the outcome as regards the rations containing a pound and a half of protein or more a day is fairly definite, indicating that they were sufficient to enable the cows to maintain their body weights and to make a reasonable amount of milk at the same time, the results when the very low protein ration was fed were quite unlike those secured with the more proteinous diets. Seven young cows, from four to eight years old, were placed on the very low protein ration in the fall of 1914 and it was fed to them for two to four lactations. Two completed two, and five, four lactations. Six of the seven weighed less in the second than the first lactation. Of the five which completed four lactations all weighed less than in the first lactations in both of the later lactations. These five cows were 4, 5, 5, 7 and 8 years old when they started in the trial. Three certainly should have increased in weight because of age. The shrinkages in the fourth lactation as compared with the first were 9, 5, 7, 5 and 3 percents. The average cow, a little less than 6 years old at the outset and weighing 850 pounds, four years later weighed only 780 pounds. The following comparison is illuminating in this connection:

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[1] See pp. 107-120.

| No. of cows | Fed continuously | Average age at outset | Average weight first lactation | Average weight fourth lactation | Gain or loss in weight |
|---|---|---|---|---|---|
| 7 | Low protein ration.... | 4½ | 792 | 898 | +106 |
| 4 | Medium protein ration. | 6½ | 951 | 1031 | +80 |
| 4 | High protein ration... | 7 | 963 | 985 | +22 |
| 4 | Very low protein ration | 6— | 850 | 780 | —70 |

Clearly the cows fed the very low protein ration, which normally should have gained in weight had their food intake permitted such gain, maintained their milk flows at the sacrifice of their body weights.

The lactation alternation data cannot be used to quite the same advantage in connection with the very low protein trials of 1914-1919. Unfortunately, failure properly to supervise the feeding during the third lactation in 1916-17 introduced errors which almost entirely ruined this phase of the work. However, six cows fed the very low ration during one lactation without exception weighed less during the next one than they did during the first one, four being fed the low ration and two continued on the very low one. Two cows fed the low ration during the initial and the very low one during the second lactation, weighed less during the second than during the first. Four were young cows, one seven years old and one was aged. The only plus signs occur in two cases (Catrina 2nd, Theta) wherein the use of a low ration followed that of a low ration. In the eight comparisons where the very low ration was fed during either lactation, the average weight during the second lactation was invariably lower than it was during the first, the average shrinkage approximating 5 percent.

It seems quite clear that, whereas the very low protein ration carrying approximately a pound of digestible protein daily was insufficient to enable the cows to produce their normal milk flows and to maintain their bodily status, the low protein ration carrying 1.5 pounds of digestible protein daily furnished ample amounts to enable the cows to hold and to increase their live weights, that, indeed, in this respect it outclassed its competitors.

### 2. DURING SHORT FEEDING PERIODS

The time honored system of judging the relative value of rations by means of feeding trials has been the so-called alternation method, wherein cows have been fed for a series of weeks upon a definite ration, then fed for a similar number of weeks upon the competing ration, to be, at the opening of the next period, again placed upon the ration first fed, then again in due time to be swung back to the second ration fed, and so on. Considerable study, much of it carried on at this Station,[1] has seemed to indicate that if the feeding periods were not less than five weeks long, the data obtained were liable to afford results which were trustworthy and relatively free from error. Under ideal conditions the adoption of the five-week period enables one, located in a northern climate such as is that which obtains in Vermont, to make use of five feeding periods between the time when the cows come into the barn for the winter in early November and their exit therefrom for pasture in late mid-May.

During the years prior to 1906, it has been the custom at this Station in the conduct of feeding trials to change the cows from one ration to the other somewhat gradually, taking usually three to four days for the purpose; to take into account in comparative measurements only records secured in the final three weeks of each feeding period; rigorously to scan every record and to exclude such as evidenced abnormality of any sort which was clearly due to extraneous causes; to reject also the records where marked changes occurred in milk flow which were obviously due to approaching drying off or to very recent calving; and to use only data which were clearly representative. This custom has been followed in the conduct of the trials now under consideration.

Furthermore, for purposes of comparison under the conditions cited above, it has been the custom to assume that the mean of the consumption data and of the production data secured in the experimental portions (i. e., the three weeks following the initial two weeks' feeding on a given ration) of two non-adjacent feeding periods in which identical rations were fed, would have been likely to have been the data of consumption and production which would have been secured in the experimental portion of the intervening feeding period had the ration fed been that which, as a matter of fact, was fed in the two non-adjacent periods, or, in other words, had continuous and unchanged feeding occurred instead of intermittent feeding. These assumed data, these averages, afforded a reasonably accurate basis of comparison of what might be termed computed fact with fact, of what presumedly would have been and of what was. The scheme enabled the computer to set side by side the results which it is fair to assume would have been secured by feeding ration B during a given period—since the data were the average of results secured before and after the period in question—with the results which actually were secured during the period under survey by feeding ration A. In short, a direct comparison of actual consumption and production data with hypothetical consumption and production data was thus made possible. These data, thus computed, have been familiarly known in our parlance as the "ghost" figures. The number of such comparisons being relatively large, the errors introduced by the use of these ghosts are minimized. This system enables one in a fairly satisfactory manner to counteract the effect of advancing lactation and of other factors making for irregularity of food consumption and milk flow.[1]

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[1] Vt. Sta. Rpts. 10, pp. 146-161 (1897); 11, pp. 320-330 (1898); 20, pp. 463-464 (1907).

When the trials now under discussion were being shaped in the fall of 1906, it was clearly foreseen that there then were and would be during the years to come several cows in the herd which for divers reasons, more particularly their age, could not be safely started on the longtime trials which constituted the vertebral column of the experiment. It would have been useless, for instance, to have scheduled Lady Perusia to start on December 2, 1906, on a feeding trial which was expected to last four and which really lasted almost 13 years, to have given her a "long continuous" sentence. Lady Perusia was 13 years old in November, 1906, and her days of usefulness were all but over. But she could be used and was used to good advantage for two seasons in the short alternation work, furnishing excellent data. Similarly heifers with their first calf, indeed with their second calf, their capabilities more or less unknown, could not be scheduled with safety in trials wherein it was desired to make conditions in competitive groups as comparable as possible, and wherein the scrutiny of past records made under known conditions was an important factor in the determination of probable uniformity and of location in the trials in this, that, or the other group. In order to make use of these otherwise unavailable animals and, as well, to test the accuracy of the results attained by the short alternation system as compared with those secured by the more costly and time consuming processes, namely, the "lactation alternation" and the "long continuous" modes of feeding employed with the bulk of the herd, the trials reported in this section of the discussion were inaugurated and carried on coincidently with the more fundamental studies.

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[1] For further discussion of this general matter and for a review of the relative merits of diverse methods of the conduct of feeding trials, see Vt. Sta. Rpts. 14, pp. 369-375 (1901); 15, pp. 318-337 (1902); 16, pp. 264-274 (1903); 17, pp. 511-523 (1904); 18, pp. 405-412 (1905); 19, pp. 332-336 (1906).

### COMPARISONS OF HIGH, MEDIUM AND LOW PROTEIN RATIONS

Three comparisons were made:

(1) Of the high and the low protein rations.
(2) Of the high and the medium protein rations.
(3) Of the medium and the low protein rations.

The data secured during the months of November to May, inclusive in six seasons, 1906-07 to 1911-12, were collated as a unit, those secured in 1912-13 as another unit, and those obtained in 1913-14 as still another unit. These separations were made with a view of determining the likenesses or unlikenesses of the outcomes, of noting whether a single season's trial, using a moderate number of animals, might be expected to afford approximately accurate results, for obviously in the generality of trials it is quite out of the question to feed rations for eight years before determining the nature of the outcome.

The following tabulation shows something as to the scope of the work and the volume of figures available for use in the comparative study.

| Season of | Number of cows used | Total number of separate trials | Average number of separate trials per year | Total number of feeding periods | Average number of feeding periods per year | Days of feeding in experimental portions of periods |
|---|---|---|---|---|---|---|
| COMPARISON OF HIGH PROTEIN AND LOW PROTEIN RATIONS | | | | | | |
| 1906-1912 .......... | 29 | 43 | 7+ | 113 | 19— | 2373 |
| 1912-1913 .......... | 4 | 4 | 4 | 10 | 10 | 210 |
| 1913-1914 .......... | 3 | 3 | 3 | 12 | 12 | 252 |
| COMPARISON OF HIGH PROTEIN AND MEDIUM PROTEIN RATIONS | | | | | | |
| 1906-1912 .......... | 24 | 30 | 5 | 85 | 14+ | 1785 |
| 1912-1913 .......... | 3 | 3 | 3 | 10 | 10 | 210 |
| 1913-1914 .......... | 3 | 3 | 3 | 9 | 9 | 189 |
| COMPARISON OF MEDIUM PROTEIN AND LOW PROTEIN RATIONS | | | | | | |
| 1906-1912 .......... | 25 | 33 | 5½ | 88 | 15— | 1848 |
| 1912-1913 .......... | 4 | 4 | 4 | 11 | 11 | 231 |
| 1913-1914 .......... | 3 | 3 | 3 | 10 | 10 | 210 |

The results of this study of the efficacy of short alternation feeding trials, as well as of the outcome as between the three rations, are presented in nine statements (pages 111-114). Of course three deal with comparisons of the high and low protein rations, three with those of the high and medium protein rations and three with those of the medium and low protein rations. The results are expressed in terms of a single day's feeding and production. The seven columns at the extreme left of each table deal with food consumption; the next eleven columns with milk production; and the last eight columns with milk production standardized to a definite food consumption.

SHORT ALTERNATION TRIALS

| | | Food consumption | | Digestible nutrients in food eaten | | | | | Composition of milk | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total dry matter | Digestible dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract | Milk | Total solids | Fat | Casein, albumin, etc. | Milk sugar | Ash |
| | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % | % |
| 1906-12 | High ........ | 22.48 | 14.66 | 0.55 | 2.38 | 3.18 | 7.66 | 0.58 | 16.12 | 14.86 | 5.28 | 3.88 | 4.93 | 0.76 |
| | Low ........ | 22.34 | 14.40 | 0.54 | 1.52 | 3.14 | 8.56 | 0.51 | 15.47 | 14.84 | 5.26 | 3.81 | 4.97 | 0.76 |
| | ± ........... | +0.14 | +0.26 | +0.01 | +0.86 | +0.04 | —0.90 | +0.07 | +0.65 | +0.02 | +0.02 | +0.07 | —0.04 | 0 |
| | % ........... | +0.6 | +1.8 | +2 | +56.9 | +1.2 | —10.5 | +14.8 | +4.2 | +0.1 | +0.4 | +2.1 | —0.8 | 0 |
| 1912-13 | High ........ | 22.20 | 14.57 | 0.51 | 2.52 | 2.98 | 7.67 | 0.78 | 19.07 | 14.83 | 5.24 | 3.65 | 5.16 | 0.78 |
| | Low ......... | 22.38 | 14.56 | 0.51 | 1.52 | 2.97 | 8.76 | 0.70 | 18.21 | 14.85 | 5.25 | 3.52 | 5.35 | 0.75 |
| | ± ........... | —0.18 | +0.01 | 0 | +1.00 | —0.01 | —1.09 | +0.08 | +0.86 | —0.02 | —0.01 | +0.13 | —0.19 | +0.03 |
| | % ........... | —0.8 | +0.1 | —0.2 | +65.9 | +0.3 | —12.5 | +11.9 | +4.7 | —0.1 | —0.2 | +3.7 | —3.5 | +4. |
| 1913-14 | High ........ | 16.84 | 10.97 | 0.39 | 1.76 | 2.47 | 5.68 | 0.46 | 11.16 | 16.15 | 6.14 | 4.04 | 5.21 | 0.78 |
| | Low ........ | 16.92 | 10.90 | 0.39 | 1.16 | 2.47 | 6.36 | 0.39 | 10.97 | 16.06 | 6.09 | 3.97 | 5.26 | 0.78 |
| | ± ........... | —0.08 | +0.07 | +0.01 | +0.60 | 0 | —0.68 | +0.07 | +0.19 | +0.09 | +0.05 | +0.07 | —0.05 | 0 |
| | % ........... | —0.4 | +0.7 | +1.6 | +52.2 | —0.1 | —10.7 | +16.8 | +1.7 | +0.6 | +0.8 | +1.7 | —1 | 0 |
| 1906-12 | High ........ | 22.49 | 14.66 | 0.58 | 2.37 | 3.23 | 7.61 | 0.58 | 15.07 | 15.51 | 5.70 | 4.16 | 4.84 | 0.79 |
| | Medium ..... | 22.48 | 14.50 | 0.57 | 1.93 | 3.23 | 8.02 | 0.49 | 14.53 | 15.54 | 5.73 | 4.12 | 4.88 | 0.78 |
| | ± ........... | +0.01 | +0.16 | +0.01 | +0.44 | 0 | —0.41 | +0.09 | +0.54 | —0.03 | —0.03 | +0.04 | —0.04 | +0.01 |
| | % ........... | +0.1 | +1.1 | +1.6 | +22.7 | 0 | —5.1 | +18.4 | +3.7 | —0.2 | —0.5 | +1 | —0.8 | +1.3 |
| 1912-13 | High ........ | 19.99 | 13.12 | 0.46 | 2.16 | 2.69 | 6.91 | 0.68 | 14.93 | 16.07 | 6.09 | 3.88 | 5.35 | 0.78 |
| | Medium ..... | 19.90 | 12.95 | 0.46 | 1.75 | 2.69 | 7.27 | 0.60 | 14.62 | 16.18 | 6.14 | 3.90 | 5.41 | 0.79 |
| | ± ........... | +0.09 | +0.17 | 0 | +0.41 | 0 | —0.37 | +0.08 | +0.31 | —0.11 | —0.05 | —0.02 | —0.06 | —0.01 |
| | % ........... | +0.4 | +1.3 | +0.9 | +23.5 | 0 | 5.1 | +13.8 | +2.1 | —0.7 | —0.8 | —0.5 | —1.1 | —1.3 |

SHORT ALTERNATION TRIALS—continued

| | Production of milk solids | | | | | Production on uniform dry matter | | | | Production on uniform digestible dry matter consumption | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total solids | Fat | Casein-albumin | Milk sugar | Ash | Milk | Total solids | Fat | Solids-not-fat | Milk | Total solids | Fat | Solids-not-fat |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| High | 2.40 | 0.85 | 0.63 | 0.79 | 0.12 | 16.14 | 2.40 | 0.85 | 1.55 | 15.94 | 2.37 | 0.84 | 1.53 |
| Low | 2.30 | 0.81 | 0.59 | 0.77 | 0.12 | 15.58 | 2.31 | 0.82 | 1.49 | 15.57 | 2.31 | 0.82 | 1.48 |
| + | +0.10 | +0.04 | +0.04 | +0.03 | +0.01 | +0.56 | +0.09 | +0.03 | +0.06 | +0.37 | +0.06 | +0.02 | +0.04 |
| % | +4.3 | +4.5 | +6.3 | +3.4 | +5.1 | +3.6 | +3.7 | +3.9 | +4 | +2.4 | +2.5 | +2.7 | +2.8 |
| High | 2.83 | 1.00 | 0.70 | 0.98 | 0.15 | 19.33 | 2.86 | 1.01 | 1.85 | 18.96 | 2.81 | 0.99 | 1.82 |
| Low | 2.70 | 0.96 | 0.64 | 0.97 | 0.14 | 18.30 | 2.72 | 0.97 | 1.75 | 18.14 | 2.69 | 0.95 | 1.74 |
| + | +0.13 | +0.04 | +0.06 | +0.01 | +0.01 | +1.03 | +0.14 | +0.04 | +0.10 | +0.82 | +0.12 | +0.04 | +0.07 |
| % | +4.6 | +4.4 | +8.6 | +0.9 | +10.3 | +5.6 | +5.1 | +4.7 | +5.9 | +4.5 | +4.4 | +4.2 | +4.2 |
| High | 1.80 | 0.69 | 0.45 | 0.58 | 0.09 | 11.27 | 1.82 | 0.69 | 1.13 | 11.19 | 1.81 | 0.69 | 1.12 |
| Low | 1.76 | 0.67 | 0.44 | 0.58 | 0.09 | 11.02 | 1.77 | 0.67 | 1.10 | 11.07 | 1.78 | 0.67 | 1.11 |
| + | +0.04 | +0.02 | +0.01 | 0 | 0 | +0.25 | +0.05 | +0.02 | +0.03 | +0.12 | +0.03 | +0.01 | +0.01 |
| % | +2.3 | +2.5 | +3.4 | +0.7 | +1.2 | +2.2 | +2.7 | +3.1 | +2.4 | +1.1 | +1.6 | +1.9 | +1.2 |
| High | 2.34 | 0.86 | 0.63 | 0.73 | 0.12 | 15.07 | 2.34 | 0.86 | 1.48 | 14.91 | 2.31 | 0.85 | 1.46 |
| Medium | 2.26 | 0.83 | 0.60 | 0.71 | 0.11 | 14.67 | 2.28 | 0.84 | 1.44 | 14.53 | 2.26 | 0.83 | 1.42 |
| + | +0.08 | +0.03 | +0.03 | +0.02 | +0.01 | +0.40 | +0.06 | +0.02 | +0.04 | +0.38 | +0.05 | +0.02 | +0.04 |
| % | +3.5 | +3 | +4.8 | +2.8 | +4.4 | +2.7 | +2.5 | +2 | +2.9 | +2.7 | +2.4 | +1.9 | +2.7 |
| High | 2.40 | 0.91 | 0.58 | 0.80 | 0.12 | 14.57 | 2.34 | 0.89 | 1.46 | 14.51 | 2.33 | 0.88 | 1.45 |
| Medium | 2.36 | 0.90 | 0.57 | 0.79 | 0.12 | 14.33 | 2.31 | 0.88 | 1.45 | 14.40 | 2.32 | 0.88 | 1.46 |
| + | +0.04 | +0.01 | +0.01 | +0.01 | 0 | +0.24 | +0.03 | +0.01 | +0.01 | +0.11 | +0.01 | 0 | 0 |
| % | +1.9 | +1.5 | +1.4 | +1 | +1.8 | +1.7 | +1.4 | +1 | +0.9 | +0.7 | +0.5 | 0 | —0.1 |

SHORT ALTERNATION TRIALS—continued

| | | Food consumption | | Digestible nutrients in food eaten | | | | | Composition of milk | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total dry matter | Digestible dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract | Milk | Total solids | Fat | Casein, albumin, etc. | Milk sugar | Ash |
| | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % | % |
| 1913-14 | High ........ | 18.54 | 12.20 | 0.44 | 2.11 | 2.58 | 6.27 | 0.55 | 16.36 | 15.39 | 5.69 | 3.69 | 5.17 | 0.78 |
| | Medium ..... | 18.56 | 12.09 | 0.43 | 1.72 | 2.58 | 6.71 | 0.47 | 16.07 | 15.52 | 5.74 | 3.66 | 5.33 | 0.77 |
| | ± .......... | —0.02 | +0.11 | +0.01 | +0.39 | 0 | —0.44 | +0.08 | +0.29 | —0.13 | —0.05 | +0.03 | —0.16 | +0.01 |
| | % .......... | —0.1 | +0.9 | +2.6 | +22.7 | 0 | —6.6 | +16.8 | +1.8 | —0.8 | +0.9 | +0.5 | —3.1 | +1.3 |
| 1906-12 | Medium ..... | 22.26 | 14.40 | 0.56 | 1.93 | 3.17 | 8.00 | 0.49 | 14.53 | 15.08 | 5.38 | 3.95 | 4.93 | 0.77 |
| | Low ......... | 22.20 | 14.34 | 0.55 | 1.50 | 3.14 | 8.49 | 0.50 | 14.25 | 14.99 | 5.37 | 3.84 | 4.98 | 0.77 |
| | ± .......... | +0.06 | +0.06 | +0.01 | +0.43 | +0.03 | —0.49 | —0.02 | +0.28 | +0.09 | +0.01 | +0.11 | —0.05 | 0 |
| | % .......... | +0.2 | +0.5 | +2. | +28.7 | +0.8 | —5.7 | —3.4 | +1.9 | +0.6 | +0.2 | +2.9 | —1 | 0 |
| 1912-13 | Medium ..... | 19.10 | 12.39 | 0.46 | 1.63 | 2.65 | 6.93 | 0.55 | 13.53 | 16.22 | 6.27 | 3.90 | 5.30 | 0.79 |
| | Low ......... | 18.98 | 12.26 | 0.45 | 1.26 | 2.64 | 7.26 | 0.57 | 13.25 | 16.15 | 6.21 | 3.79 | 5.38 | 0.78 |
| | ± .......... | +0.11 | +0.13 | +0.01 | +0.37 | +0.01 | —0.33 | —0.02 | +0.28 | +0.07 | +0.06 | +0.11 | —0.08 | +0.01 |
| | % .......... | +0.6 | +1 | +1.8 | +29.8 | +0.4 | —4.6 | —3.2 | +2.1 | +0.4 | +1 | +3 | —1.5 | +1.3 |
| 1913-14 | Medium ..... | 18.14 | 11.71 | 0.43 | 1.55 | 2.68 | 6.41 | 0.47 | 12.71 | 15.99 | 6.05 | 3.97 | 5.23 | 0.76 |
| | Low ......... | 18.18 | 11.72 | 0.43 | 1.22 | 2.67 | 6.88 | 0.43 | 12.42 | 15.94 | 6.03 | 3.92 | 5.23 | 0.77 |
| | ± .......... | —0.04 | —0.01 | 0 | +0.33 | +0.01 | —0.47 | +0.04 | +0.29 | +0.05 | +0.02 | +0.05 | 0 | —0.01 |
| | % .......... | —0.2 | —0.1 | 0 | +26.6 | +0.4 | —6.8 | +9.0 | +2.3 | +0.3 | +0.3 | +1.3 | 0 | +1.3 |

SHORT ALTERNATION TRIALS—concluded

| | Production of milk solids | | | | | Production on uniform dry matter | | | | Production on uniform digestible dry matter consumption | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total solids | Fat | Casein, albumin, etc. | Milk sugar | Ash | Milk | Total solids | Fat | Solids-not-fat | Milk | Total solids | Fat | Solids-not-fat |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| High | 2.52 | 0.93 | 0.60 | 0.85 | 0.13 | 16.33 | 2.51 | 0.93 | 1.57 | 16.10 | 2.48 | 0.92 | 1.55 |
| Medium | 2.49 | 0.92 | 0.59 | 0.86 | 0.12 | 16.02 | 2.49 | 0.92 | 1.56 | 15.97 | 2.48 | 0.92 | 1.56 |
| ± | +0.02 | +0.01 | +0.02 | —0.01 | 0 | +0.31 | +0.03 | +0.01 | +0.01 | +0.13 | 0 | 0 | —0.01 |
| % | +0.9 | +1 | +2.7 | —1.3 | +3.3 | +1.9 | +1 | +1.1 | +0.7 | +0.8 | 0 | +0.1 | —0.3 |
| Medium | 2.19 | 0.78 | 0.57 | 0.72 | 0.11 | 14.69 | 2.22 | 0.79 | 1.42 | 14.62 | 2.21 | 0.79 | 1.41 |
| Low | 2.14 | 0.77 | 0.55 | 0.71 | 0.11 | 14.44 | 2.17 | 0.78 | 1.39 | 14.41 | 2.16 | 0.77 | 1.38 |
| ± | +0.05 | +0.02 | +0.02 | +0.01 | 0 | +0.24 | +0.05 | +0.01 | +0.03 | +0.21 | +0.05 | +0.01 | +0.03 |
| % | +2.6 | +2.2 | +4.7 | +0.8 | +2.8 | +1.6 | +2.3 | +2.1 | +2.2 | +1.4 | +2.1 | +1.8 | +2 |
| Medium | 2.20 | 0.85 | 0.53 | 0.72 | 0.11 | 13.81 | 2.24 | 0.87 | 1.38 | 13.92 | 2.26 | 0.87 | 1.39 |
| Low | 2.14 | 0.82 | 0.51 | 0.71 | 0.10 | 13.61 | 2.20 | 0.82 | 1.36 | 13.77 | 2.22 | 0.86 | 1.37 |
| ± | +0.06 | +0.02 | +0.02 | 0 | 0 | +0.20 | +0.04 | +0.02 | +0.02 | +0.15 | +0.04 | +0.01 | +0.02 |
| % | +2.6 | +2.9 | +4.6 | +0.6 | +2.9 | +1.5 | +1.9 | +2.4 | +1.7 | +1.1 | +1.6 | +1.9 | +1.2 |
| Medium | 2.03 | 0.77 | 0.50 | 0.67 | 0.10 | 12.96 | 2.07 | 0.78 | 1.29 | 13.02 | 2.08 | 0.79 | 1.30 |
| Low | 1.98 | 0.75 | 0.49 | 0.65 | 0.10 | 12.64 | 2.02 | 0.76 | 1.25 | 12.72 | 2.03 | 0.77 | 1.26 |
| ± | +0.05 | +0.02 | +0.02 | +0.01 | 0 | +0.32 | +0.06 | +0.02 | +0.04 | +0.30 | +0.05 | +0.02 | +0.04 |
| % | +2.6 | +2.6 | +3.5 | +2.3 | +1 | +2.6 | +2.8 | +2.8 | +3 | +2.4 | +2.7 | +2.6 | +2.8 |

A survey of the data set forth in these tables indicates:

1. That food consumption was very uniform. In but one instance was the amount of total dry matter eaten in one ration materially unlike the amount eaten in the other ration; and in but two instances (high-low, '06-'12; high-medium, '12-'13) were material differences manifested in digestible dry matter consumption, and in neither of these comparisons did the divergency exceed two percent. In other words, total food intakes were in all cases practically identical.

2. That the consumption of digestible ash and crude fiber in the competitive rations were closely similar, the divergencies but once exceeding two percent. The digestible protein intake figures were of course dissimilar—for the effect of digestible protein variation was the point in view in these studies—and, as a necessary corollary of such variation, the digestible nitrogen-free-extract consumptions were unlike. The introduction of cottonseed meal into the high protein ration naturally increased its ether extract content to some extent as compared with those of the other rations.

Nowithstanding the minor value of these variations in food consumption, it seemed desirable to place all the data on a strictly comparable basis; hence the calculations which appear in the tabulations at the extreme right.

### SIX SEASON TRIALS

The outcome of the six season trials seems to be as follows:

1. When a high protein ration was substituted for a low protein ration, approximately 2⅜ pounds of digestible protein being eaten daily instead of 1½ pounds, the deficiency being made up with an equivalent amount of digestible carbohydrates:

(*a*) Approximately 4.2 percent more milk, 4.3 percent more total solids, and 4.5 percent more fat, were made.

(*b*) On uniform dry matter consumption, approximately 3.6 percent more milk, 3.7 percent more total solids, and 3.9 percent more fat, were made.

(*c*) On uniform digestible dry matter consumption, approximately 2.4 percent more milk, 2.5 percent more total solids, and 2.7 percent more fat, were made.

2. When a high protein ration was substituted for a medium protein ration, approximately 2⅜ pounds of digestible protein eaten daily instead of about 1⁹⁄₁₀ pounds, the deficiency being made up with an equivalent amount of digestible carbohydrates:

(*a*) Approximately 3.7 percent more milk, 3.5 percent more total solids, and 3 percent more fat, were made.

(*b*) On uniform dry matter consumption, approximately 2.7 percent more milk, 2.5 percent more total solids, and 2 percent more fat were made.

(*c*) On uniform digestible dry matter consumption, approximately 2.7 percent more milk, 2.4 percent more total solids, and 1.9 percent more fat, were made.

3. When a medium protein ration was substituted for a low protein ration, approximately $1\frac{9}{10}$ pounds digestible protein being eaten daily instead of $1\frac{1}{2}$ pounds, the deficiency being made up with an equivalent amount of digestible carbohydrates:

(*a*) Approximately 1.9 percent more milk, 2.6 percent more total solids, and 2.2 percent more fat, were made.

(*b*) On uniform dry matter consumption, approximately 1.6 percent more milk, 2.3 percent more total solids and 2.1 percent more fat, were made.

(*c*) On uniform digestible dry matter consumption, approximately 1.4 percent more milk, 2.1 percent more total solids, and 1.8 percent more fat were made.

## SINGLE YEAR TRIALS

How do the data secured with a limited number of cows in single year compare with these figures?

### HIGH AND LOW PROTEIN RATION COMPARISONS

(When a high protein ration was substituted for a low protein ration)

| | Milk | | | Total solids | | | Fat | | |
|---|---|---|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (a) | (b) | (c) | (a) | (b) | (c) |
| 1906-12 ..... | +4.3 | +3.6 | +2.4 | +4.3 | +3.7 | +2.5 | +4.5 | +3.9 | +2.7 |
| 1912-13 ..... | +4.7 | +5.6 | +4.5 | +4.6 | +5.1 | +4.4 | +4.4 | +4.7 | +4.2 |
| 1913-14 ..... | +1.7 | +2.2 | +1.1 | +2.3 | +2.7 | +1.6 | +2.5 | +3.1 | +1.9 |
| Extremes ... | 3 | 3.5 | 3.4 | 2.3 | 2.4 | 2.8 | 2.0 | 1.6 | 2.3 |

### HIGH AND MEDIUM PROTEIN RATION COMPARISONS

(When a high protein ration was substituted for a medium protein ration)

| | Milk | | | Total solids | | | Fat | | |
|---|---|---|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (a) | (b) | (c) | (a) | (b) | (c) |
| 1906-12 ..... | +3.7 | +2.7 | +2.7 | +3.5 | +2.5 | +2.4 | +3 | +2 | +1.9 |
| 1912-13 ..... | +2.1 | +1.7 | +0.7 | +1.9 | +1.4 | +0.5 | +1.5 | +1 | 0 |
| 1913-14 ..... | +1.8 | +1.9 | +0.8 | +0.9 | +1 | 0 | +1 | +1.1 | +0.1 |
| Extremes ... | 1.9 | 1.0 | 2.0 | 2.6 | 1.5 | 2.4 | 2.0 | 1.0 | 1.9 |

MEDIUM AND LOW PROTEIN RATION COMPARISONS

(When a medium protein ration was substituted for a low protein ration)

| | Milk | | | Total solids | | | Fat | | |
|---|---|---|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (a) | (b) | (c) | (a) | (b) | (c) |
| 1906-12 ..... | +1.9 | +1.6 | +1.4 | +2.6 | +2,3 | +2.1 | +2.2 | +2 | +1.8 |
| 1912-13 ..... | +2.1 | +1.5 | +1.1 | +2.6 | +1.9 | +1.6 | +2.1 | +2.4 | +1.9 |
| 1913-14 ..... | +2.3 | +2.6 | +2.4 | +2.6 | +2.8 | +2.7 | +2.6 | +2.8 | +2.6 |
| Extremes ... | 0.4 | 1.1 | 1.3 | 0 | 0.9 | 1.1 | 0.7 | 0.7 | 0.8 |

The comparisons are made on the basis of the differences observed in the production on the one ration as compared with the other, the ration with the lower protein content being considered the norm and the other compared with it. The figures under (*a*), (*b*) and (*c*) respectively represent: (*a*) the differences which are actual; (*b*) the differences on a uniform, total dry matter consumption basis; and (*c*) the differences on a uniform digestible dry matter consumption basis.

Touching the table it may be said:

(1) That uniformly the trend is in one direction, i. e., plus. There is not a single discordant minus.

(2) That, speaking broadly, the results are quite comparable. Closer agreement could hardly have been attained than that secured in the three medium and low protein comparisons; and the results in the other two comparisons are quite satisfactory. In view of the fact that the experimental error incident to the short alternation system of feeding trials as conducted at this Station as determined by very many years of careful experimentation approximates 1.5 percent,[1] there seems no reason to question the essential accuracy of the measure afforded by the single year's trials with relatively few cows, made in 1912-13 and 1913-14, assuming that the method itself is capable of yielding accurate results.

The question now arises as to the relative merits as producers of milk of these three rations as judged by the short alternation system. Certain points stand out clearly.

(1) The more protein, the more milk, invariably. The daily ration containing from $1\frac{1}{2}$ to $1\frac{9}{10}$ pounds of digestible protein made more milk and total solids than did one containing from $1\frac{1}{4}$ to $1\frac{1}{2}$ pounds; the daily ration containing from $2\frac{1}{10}$ to $2\frac{3}{8}$ pounds of digestible protein made more milk and total solids than did one containing from $1\frac{7}{10}$ to $1\frac{9}{10}$ pounds; and the daily ration containing from $2\frac{4}{10}$

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[1] Vt. Sta. Rpts. 18, p. 403 (1905); 19, p. 330 (1906).

to 2½ pounds digestible protein (and in one case, 1913-14, when heifers were fed, 1¾ pounds digestible protein) made more milk and total solids than did one containing 1½ pounds digestible protein (or 1⅛ pounds in the 1913-14 heifer trial).

(2) The quality of the milk was not materially affected. However, it is interesting to note that in eight cases out of nine, the casein contents of the milk made when relatively high nitrogenous rations were fed were somewhat higher than when the less proteinous rations were fed, and that in the ninth case the casein percentages of the two milks were practically identical. Furthermore, it is interesting to note that in eight cases out of nine the milk sugar contents of the milk made when a relatively highly carbohydrate ration was fed was higher than was the case when rations carrying less digestible carbohydrates were fed, and that in the ninth case the milk sugar percentages of the two milks were identical. This point is discussed at greater length on pages 129 to 131.

(3) If one were to attempt to state the outcome on the basis of the results attained in these short alternation trials, one would be forced to say, speaking broadly, that the high protein ration was capable of making approximately three and a half percent more milk and total solids than the low protein ration; that the high protein ration was capable of making approximately two percent more milk and solids than the medium protein ration; and that the medium protein ration was capable of making approximately two and a half percent more milk and solids than the low protein ration; and, in view of the unvarying uniformity of the trend of the results, and the comparatively narrow margin of divergence in the outcome as measured in a six-year period and in two one-year periods, that the experimental error incident to the short alternation method of feeding trials in these instances did not function to such an extent as materially to affect the outcome.

(4) The relative economy of the rations fed was not a factor in these trials. However, the outcome can be expressed in general terms, making it possible for the reader to apply it to any given case. Assuming that similar results would be likely to be atttained whenever similar rations, supplying roughly 2½, 2 and 1½ pounds of digestible protein, were fed daily to the average cow—an assumption which is so sweeping as to be very questionable—one might reason that if 100 pounds of milk were made on the low protein ration, about 102 pounds

might be expected as a result of feeding the medium protein ration and, perhaps, 104 pounds following the use of the high protein ration, provided essentially equivalent amounts of digestible dry matter were eaten in each case. Bearing this statement in mind and having in hand the prices at which from time to time concentrates are selling, a dairyman may determine for himself whether or not such a calculated increase would offset the possible higher cost of any given ration. All of which reasoning may be applicable in some instances and in others be little better than guess work. However, it should not be forgotten in this connection that an extra pound of digestible protein eaten by a cow means an extra sixth of a pound of nitrogen voided in manure, worth, at the prices ruling in the days before the war, about four cents. In a herd of 25 cows, this means a dollar a day. This matter is discussed at length on pages 131 to 137.

### 3. THE RELATIVE TRUSTWORTHINESS OF RESULTS SECURED IN TRIALS OF MANY YEARS' DURATION AND IN TRIALS OF SHORT DURATION

How may the merits of a given system of feeding, of a given ration, of a given roughage or concentrate, best be determined? How can the worth of such a system, ration, roughage or concentrate as compared with another be most accurately measured? Was either of the methods employed in these trials to be preferred, namely:

(1) *Long continuous* feeding for a series of years, a system whereby a definite ration was fed continuously year in and year out to one set of animals, while a different ration was similarly fed to another set of animals, the divergencies in the outcome, if any such occurred, being deemed to be due to differences in the productive values of the two rations rather than to differences between the productive abilities of the competing groups of cows.

(2) *Lactation alternation* feeding for a series of years, a system whereby during alternate lactations a cow is fed the competing rations; e. g., during one lactation the low protein ration, during the following lactation the high protein ration, during the lactation next following the low protein ration, then during the next lactation the low protein ration and so on; the divergencies in the outcome, if any such occurred, being deemed to be due to differences in the productive values of the two rations, in view of the fact that the bovine personal equation is eliminated by the use of the same individual.

(3) *Short alternation* feeding during the barn-life period of the year, November to May, a system whereby during alternating periods of five weeks' duration, a cow is fed the competing rations, e. g., the low, the high, the low, the high and the low protein rations, the divergencies in the outcome, if any such occurred, being deemed to be due to differences in the productive values of the two rations in view of the elimination of the bovine personal equation.

This matter was under survey for six years (1901-1906) at this Station and much data accumulated,[1] the study of which led the writer to feel that the alternation system was to be preferred to that of continuous feeding as a means of measurement. However, in these comparisons, alternations occurred every five weeks; they were "short alternations." The question now arises, as stated above, namely, as to the relative merits of the three systems employed in this longtime trial of 1906-1921. It is obvious that few trials can be profitably conducted for 15 years before a result is secured, or, indeed, for five years; that if a reasonably accurate outcome can be obtained at the end of a single feeding season, at a relatively small outlay in time, effort and money, it were better thus to plan and to feed.

It is thought that the general outcome in this prolonged trial serves on the whole to substantiate the general statement that, in so far as the direct returns in production are concerned, disregarding the effect on the continued physical well-being of the animal which might result from long continued usage of, for example, a very restricted ration, the short alternation trials gave results which were not materially unlike those afforded by the longtime experiments.

## IV. THE PERCENTAGE RECOVERY IN THE MILK FLOW OF THE DIGESTIBLE NUTRIENTS DERIVED FROM RATIONS WIDELY DIVERSE IN THEIR DIGESTIBLE PROTEIN CONTENTS

What was the percentage recovery in the milk flow of the digestible ingredients in the several rations which were fed during these trials?

The data in the large tables are quite significant touching this matter. The essential and average figures are as follows, expressed in terms of percentages, being averages of averages in Tables A to F, inclusive, folded in opposite page 64, using lactation alternation data only. The divergencies between the lowest and the highest figures, if in excess of 10 percent of the lower, are indicated; if less than 10 percent they are omitted, as being relatively unimportant, if not, indeed, within the limits of experimental error.

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[1] See footnote, page 108.

| | Starch equivalent utilized for | | Digestible protein utilized for | | Carbohydrates and (fat × 2¼) utilized for | | Crude ash in feed utilized in milk | Starch equivalent less maintenance utilized for milk | Digestible protein less maintenance utilized for milk | Carbohydrates and (fat × 2¼) less maintenance utilized for milk |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maintenance[1] | Milk | Maintenance[1] | Milk | Maintenance[1] | Milk | | | | |
| | % | % | % | % | % | % | % | % | % | % |
| Tables A and C | Complete lactations | | | | | | | | | |
| Low protein ration...... | 59.7 | 28.1 | 49.3 | 47.7 | 61.0 | 25.7 | 28.9 | 69.7 | 94.2 | 65.8 |
| Medium protein ration.. | 61.1 | 29.6 | 38.1 | 38.4 | 64.8 | 28.2 | 29.6 | 76.1 | 62.0 | 80.2 |
| High protein ration..... | 60.0 | 29.0 | 30.2 | 30.7 | 66.3 | 28.7 | 30.4 | 72.5 | 44.0 | 85.1 |
| Percentage differences... | ... | ... | 63.2 | 55.3 | ... | 11.8 | ... | ... | 110.0 | 29.1 |
| Tables B and D | Winter periods | | | | | | | | | |
| Low protein ration...... | 52.3 | 21.5 | 43.7 | 38.3 | 53.3 | 19.6 | 21.7 | 45.0 | 68.0 | 41.8 |
| Medium protein ration.. | 52.1 | 22.4 | 33.6 | 30.4 | 55.0 | 21.1 | 22.8 | 46.7 | 45.8 | 46.9 |
| High protein ration..... | 49.9 | 23.5 | 26.4 | 26.1 | 54.7 | 23.0 | 23.9 | 47.0 | 35.4 | 50.8 |
| Percentage differences... | ... | ... | 65.5 | 46.8 | ... | 17.4 | ... | ... | 92.1 | 21.6 |
| Table E | Complete lactations | | | | | | | | | |
| Very low protein ration.. | 70.6 | 34.3 | 77.9 | 71.7 | 70.0 | 29.6 | 33.2 | 113.2 | 328.2 | 111.4 |
| Low protein ration...... | 68.6 | 31.8 | 60.3 | 56.0 | 69.3 | 29.0 | 31.8 | 101.2 | 140.6 | 102.2 |
| Percentage differences... | ... | ... | 29.2 | 28 | ... | ... | ... | 12 | 132 | .... |
| Table F | Winter periods | | | | | | | | | |
| Very low protein ration.. | 48.7 | 26.7 | 54.4 | 58.1 | 48.2 | 23.8 | 26.6 | 51.7 | 128.1 | 45.9 |
| Low protein ration...... | 51.6 | 27.8 | 43.4 | 46.5 | 53.0 | 25.7 | 27.1 | 57.5 | 81.8 | 53.9 |
| Percentage differences... | ... | ... | 25.3 | 25 | ... | ... | ... | 11.3 | 56.6 | 17.5 |

[1] 0.7 pounds digestible protein, 7.925 pounds total digestible nutrients per 1,000 pounds live weight. See in this connection statement concerning maintenance figures on page 128; see also discussion of maintenance in bulletin 226.

It is obvious that, as between the different rations, the proportions of the various nutrients used for maintenance and for production purposes were essentially uniform in respect to:

(1) *Starch equivalent.* For maintenance purposes: (A and C) 59-61.1 percents; (B and D) 49.9-52.3 percents; (E) 68.6-70.6 percents; (F) 48.7-51.6 percents. For production purposes: (A and C) 28.1-29.6 percents; B and D) 21.5-23.5 percents; (E) 31.8-34.3 percents; (F) 26.7-27.8 percents.

(2) *Carbohydrates and (fat × 2¼).* For maintenance purposes: (A and C) 61-66.3 percents; (B and D) 53.3-55 percents; (E) 69.3-70 percents; (F) 48.2-53 percents. For production purposes (in two instances): (E) 29-29.6 percents; (F) 23.8-25.7 percents.

(3) *Crude ash.* For production purposes: (A and C) 28.9-30.4 percents; (B and D) 21.7-23.9 percents; (E) 31.8-33.2 percents; (F) 26.6-27.1 percents.

(4) *Starch equivalent (less maintenance).* For production purposes (in two instances): (A and C) 69.7-76.1 percents; (B and D) 45-47 percents.

(5) *Carbohydrates and (fat × 2¼) (less maintenance).* For production purposes (in one instance): (E) 102.2-111.4 percents.

On the other hand, it is equally obvious that, as between the different rations, the proportions of the various nutrients used for maintenance and for production purposes were highly unlike in respect to:

(1) *Digestible protein.* For maintenance purposes: (A and C) 30.2, 38.1, 49.3 percents respectively, for the high, the medium and the low protein rations; (B and D) 26.4, 33.6, 43.7 percents; (E) 60.3, 77.9 percents respectively for the low and very low protein rations; (F) 43.4, 54.4 percents. For production purposes: (A and C) 30.7, 38.4, 47.7 percents; (B and D) 26.1, 30.4, 38.3 percents; (E) 56, 71.7 percents; (F) 46.5, 58.1 percents.

(2) *Carbohydrates and (fat × 2¼).* For production purposes (in two instances): (A and C) 25.7-28.7 percents; (B and D) 19.6-23 percents.

(3) *Digestible protein (less maintenance).* For production purposes: (A and C) 44, 62, 92.4 percents; (B and D) 35.4, 45.8, 68 percents; (E) 140.6, 328.2 percents; (F) 81.8, 128.1 percents.

(4) *Carbohydrates and fat (fat × 2¼) (less maintenance).* For production purposes (in three instances): (A and C) 65.8-84.9 percents; (B and D) 41.8-50.8 percents; (F) 45.9, 53.9 percents.

Which, being interpreted, means that digestible protein utilization varied profoundly with the ration fed and that carbohydrate usage for production purposes varied with the ration fed to a much less extent and inversely to the protein variation. All of which was to be expected.

It is interesting to note that in several instances in the very low protein feeding (and in one instance in the low protein feeding) the total usage expressed in terms of percentage totals more than 100, which at once casts a shadow of doubt upon the validity of the maintenance figures (0.7, 7.925) arbitrarily adopted at the outset of the trials. It should be remarked, however, that they were standard figures then (1906) universally accepted. In the discussion concerning maintenance standards in the early part of bulletin 226, this fact is clearly set forth, namely, that 0.7 digestible protein and 7.925 pounds total digestible nutrients per 1,000 pounds live weight were the figures proposed—and within a few years— by Wolff-Lehmann (as modified by Morrison), by Haecker, by Savage, by Woll and Humphrey, all of them past masters in animal nutrition work. However, more recently, as is likewise shown in bulletin 226, Armsby and Eckles have suggested 0.5 pounds true protein and 6 therms per 1,000 pounds live weight, which, as the writer has indicated in that issue, are equivalent to 0.595 pounds digestible protein and 6.48 pounds total digestible nutrients per 1,000 pounds live weight. Had the long time and extensive maintenance trials, which ran simultaneously with the protein trials and which are discussed in bulletin 226, been completed in advance of the vast amount of computation upon which tables A to F, inclusive, were predicated, or if Armsby's or Eckles' statements had been published, it is quite probable that lower maintenance figures would have been chosen for computation purposes. However, bulletin 226 had not been written; 0.7 and 0.925 were the only and the universally accepted maintenance figures then extant. Furthermore, these and these only have been employed until within a very few years when Armsby and Eckles suggested lower figures. The re-handling and the recomputation of the data on more than 300 pounds of paper and ink was too appalling a task to undertake. However, anyone who desires to re-calculate on the Armsby-Eckles basis may do so, using the data on the tables A to F, inclusive, reducing the figures to those which would have been secured had the Armsby-Eckles standard been employed, by multiplying the "starch equivalent" figures in columns 35 and 38 by 0.818, the "digestible protein" figures in columns 36 and 40 by 0.857 and the "carbohydrates and (fat × 2¼)" figures in columns 37 and 42 by 0.814; and the "starch equivalent-" "digestible protein-" and "carbohydrates, etc.-" "(less maintenance) utilized for milk" data in columns 45, 46 and 47, and the "available starch equivalent" figures in columns 55 to 61, inclusive, by factors which will vary according to differences in the figures in columns 12, 14, 18, 30, 33 and 34.

The following statement sets forth the changes wrought in table A, using closely approximate average figures, that is to say, the average of the 27 figures in each perpendicular column. It may serve as a guide to anyone who may desire to re-work these data on the Armsby-Eckles basis.

| | Wolff-Lehmann et al. figures | Multipliers | Armsby-Eckles figures | Columns in table A |
|---|---|---|---|---|
| Starch equivalent utilized for maintenance | 7.1 lbs. | 0.818 | 5.80 lbs. | 35 |
| Digestible protein utilized for maintenance | 0.62 lbs. | 0.857 | 0.53 lbs. | 36 |
| Carbyhydrates, etc., utilized for maintenance | 6.48 lbs. | 0.814 | 5.27 lbs. | 37 |
| Starch equivalent utilized for maintenance | 60.5% | 0.818 | 49.4% | 38 |
| Digestible protein utilized for maintenance (low protein) | 49.6% | 0.857 | 42.5% | 40 |
| Digestible protein utilized for maintenance (medium protein) | 38.6% | 0.857 | 33.1% | 40 |
| Digestible protein utilized for maintenance (high protein) | 30.1% | 0.857 | 25.8% | 40 |
| Carbohydrates, etc., utilized for maintenance | 64. % | 0.814 | 52. % | 42 |
| Starch equivalent (less maintenance) utilized for milk | 72.1% | .... | 56.3%[1] | 45 |
| Digestible protein (less maintenance) utilized for milk (low protein) | 95.3% | .... | 82.9%[2] | 46 |
| Digestible protein (less maintenance) utilized for milk (medium protein) | 61.6% | .... | 56.4%[3] | 46 |
| Digestible protein (less maintenance) utilized for milk (high protein) | 43.7% | .... | 40.9%[4] | 46 |
| Carbohydrates, etc. (less maintenance) utilized for milk | 76. % | .... | 56.6%[5] | 47 |
| Seven columns to right of table | ... | 0.781* | ... | 55-61 |

[1] 3.34 (Average starch equivalent in milk—Col. 33) + 11.74 (Average starch equivalent in food—Col. 12) — 5.80 (Armsby-Eckles starch equivalent).

[2] 0.605 (Average digestible protein in milk—Col. 30) ÷ 1.26 (Average digestible protein in food—Col. 14) — 0.53 (Armsby-Eckles digestible protein).

[3] 0.615 (Average digestible protein in milk—Col. 30) ÷ 1.62 (Average digestible protein in food—Col. 14) — 0.53 (Armsby-Eckles digestible protein).

[4] 0.63 (Average digestible protein in milk—Col. 30) + 2.07 (Average digestible protein in food—Col. 14) — 0.53 (Armsby-Eckles digestible protein).

[5] 2.73 (Average carbohydrates, etc., in milk—Col. 34) ÷ 10.10 (Average carbohydrates, etc., in food—Col. 18) — 5.27 (Armsby-Eckles digestible carbohydrates, etc.).

*Average starch equivalent in food (11.74) less Wolff-Lehmann et al. average starch equivalent (7.10) = 4.64. 11.74 less Armsby-Eckles average starch equivalent (5.80) = 5.94. 4.64 ÷ 5.94 = 0.781.

An interesting set of figures are secured when the records of the several cows used in the long time trials and in the maintenance trials (bulletin 226) are compared as to their nutrient intakes and production, segregated into groups on the basis of the fat percentages in their milks. The data do not include all the records or, indeed, the majority of them. They were gathered somewhat early (1913) in the course of the trials. However, they represent 119 different lactations and seem to be sufficient in number to warrant at once their presentation and an attempt at generalization. Roughly three-sevenths of the lactations were of cows used in the long continuous trials; three-sevenths of cows used in the lactation alternation trials; and one-eighth in the maintenance trials discussed in bulletin 226. Obviously, in view of the fact that the cows were fed rations so very unlike in respect to their digestible protein contents as were the so-called low, medium, and high protein rations, the percentages of protein recovery in the milk necessarily were variable. The results in the 119 cases in the milk necessarily were variable. The figures are not particularly startling. They are just what might have been expected.

The nutrient intake and production data, assembled on the basis of the fat percentages in the milk, covering 119 cases, are set forth in the following tables:

| | Low protein | Medium protein | High protein |
|---|---|---|---|
| Number of lactations | 39 | 42 | 38 |
| Average percentage of protein recovery | 41.7 | 31.4 | 26 |
| Range of the percentage of protein recovery | 52-29 | 49-20 | 38-18 |
| Five-sixths of the records within range percentage of protein recovery | 48-36 | 34-26 | 31-22 |

| Number of cows | | | | Average digestible protein content of ration | Fat percentage | Composition of milk | | | | | Nutrients consumed; average per cow | | | | Nutrients produced; average per cow | | | | Nutrient consumption (100) : nutrient production | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | Low protein | Medium protein | High protein | | | Total solids | Fat | Casein, albumin, etc. | Milk sugar | Starch equivalent | Digestible protein | Digestible carbohydrates | Digestible fat | Total digestible nutrients | Casein and albumin | Milk sugar | Fat | Starch equivalents | Protein | Carbohydrates | Fat | Starch equivalents |
| | | | | | From To | % | % | % | % | % | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| 11 | 3 | 5 | 3 | 2 lbs. | 3¼-3¾% | 12.61 | 3.38 | 3.04 | 4.84 | 15.48 | 510.1 | 2809.8 | 142 | 3639.4 | 159.9 | 255 | 177.9 | 815.2 | 31.4 | 9.1 | 125.3 | 22.4 |
| 7 | 4 | 3 | 0 | 1.7 lbs. | 3¾-4¼% | 12.93 | 4.02 | 3.36 | 4.79 | 17.20 | 395.8 | 2645.8 | 129.6 | 3333.1 | 151.2 | 215.6 | 180.9 | 773.8 | 38.2 | 8.2 | 139.6 | 23.2 |
| 13 | 4 | 5 | 4 | 2 lbs. | 4¼-4¾% | 13.68 | 4.52 | 3.68 | 4.71 | 18.58 | 414.7 | 2442.3 | 118 | 3122.5 | 133.2 | 170.3 | 163.6 | 671.5 | 32.1 | 7 | 138.7 | 21.5 |
| 41 | 12 | 11 | 18 | 2.1 lbs. | 4¾-5¼% | 14.44 | 4.99 | 3.79 | 4.89 | 19.84 | 407.6 | 2243.8 | 116.4 | 2913.2 | 124.2 | 160.1 | 163.4 | 649.6 | 30.5 | 7.1 | 140.5 | 22.8 |
| 23 | 8 | 9 | 6 | 2 lbs. | 5¼-5¾% | 15.05 | 5.46 | 3.91 | 4.90 | 21.10 | 380.4 | 2224.8 | 110.3 | 2853.2 | 117.9 | 147.9 | 164.8 | 636.7 | 31 | 6.7 | 149.5 | 22.3 |
| 18 | 5 | 6 | 7 | 2 lbs. | 5¾-6¼% | 15.80 | 5.98 | 4.09 | 4.94 | 22.47 | 398.3 | 2212.3 | 113.2 | 2865.1 | 125.3 | 151.2 | 183.1 | 688.4 | 31.5 | 6.8 | 161.8 | 24 |
| 6 | 3 | 3 | 0 | 1.8 lbs. | 6¼-6¾% | 16.40 | 6.44 | 4.22 | 4.94 | 23.65 | 343.6 | 2421.2 | 101.4 | 2993 | 116.1 | 135.9 | 177.3 | 605.7 | 33.8 | 5.6 | 174.7 | 21.7 |
| 119 | 39 | 42 | 38 | | | | | | | | | | | | | | | | | | | |

Were it not for the fact that the cows were so evenly distributed among the three groups fed the three rations, one could not safely reason as to the relationship of milk quality to nutrient recovery; but, the above table to the contrary notwithstanding, it can be done, provided one rules out, so far as digestible protein usage is concerned, the records of group 2 (3¼-4¼%) and group 7 (6¼-6¾%). These contained no cows fed the high protein ration. The high ratios 100: 38.2 and 100: 33.8 indicate the effect of the cows fed the low protein ration without the offset of the records of those fed the high protein ration. The offsets in groups 1 and 3 are exact; in groups 5 and 6 (taken as a unit), exact. The slightly lowered ratio in group 4 (100: 30.5) shows the effect of a preponderance of high protein fed cows.

It is quite obvious, so far as this comparison is concerned, dealing entirely with the percentage figures at the right of the tabulation:

(1) That the protein returns in the form of milk made by the thin milking cows, in proportion to the digestible protein eaten, are relatively as high as those made by the rich milking cows. (3¼-3¾%, 31.4; 4¼-5¼%, 31.3; 5¼-6¼%, 31.3.)[1]

(2) That the milk sugar returns made by the thin milking cows, in proportion to the digestible carbohydrates eaten, tend to be greater than those made by the rich milking cows. (3¼-4¼%, 8.7; 4¼-5¼%, 7.1; 5¼-6¼%, 6.8; 6¼-6¾%, 5.6.)

(3) That the fat returns made by thin milking cows, in proportion to digestible fat eaten (a comparison which, it must be confessed, means little, if anything), is much lower than those made by the rich milking cows. (3¼-4¼%, 132.5; 4¼-5¼%, 139.6; 5¼-6¼%, 155.7; 6¼-6¾%, 174.7.)

(4) That the starch equivalent returns made by the thin milking cows, in proportion to the total digestible nutrients eaten, is not materially unlike that made by those making richer milk. (3¼-4¼%, 22.8; 4¼-5¼%, 21.9; 5¾-6¼%, 23.2; 6¼- 6¾%, 21.7.)

(5) That as the milk grew richer from grade to grade, two-thirds of the total solid increments of the thinner milks (less than 5¼% fat) were fat and two-fifths casein and albumin, whereas for those milks carrying more than 5¼% fat, three-fourths were fat and one-fourth casein and albumin. On this account the ratios of total

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[1] The record of groups 2 and 7 are excluded in this comparison for the reason indicated above. If the disparity of the number of cows fed the high protein ration in group 4 is compensated for the 30.5 figure becomes 33.3 and the average in the 4¼-5¼% statement above, 32.7.

solids to starch equivalents in the milks carrying less than 5¼% fat averaged 1 : 1.79 and of those carrying more than 5¼% fat 1 : 1.95. In other words, the total solids and fat percentages moved upwards in the both groups from 4 to 6.4% fat by very even increments, whereas the casein and albumin percentage upward steps were less than half as wide for the last comparison as for the first two. This fact has long been recognized.

## V. THE VALIDITY OF THE CURRENT FEEDING STANDARDS

The feeding standard situation is discussed at much length throughout the maintenance bulletin No. 226. In that publication it is stated that in the writer's (J. L. H.) judgment there are standards enough and to spare, standards which are fairly satisfactory and that, consequently, no others are proposed, despite the fact that the volume of data on which bulletins 225 and 226 are erected greatly exceeds, indeed many times exceeds, that with which the author of any standard heretofore proposed has had to deal. To this discussion the interested reader, if such there be, is directed.

The trials discussed in this bulletin were not designed to test the validity or to measure the applicability of any of the so-called feeding standards. However, the outcome obviously tends at least to raise the question whether the standards set forth for milking cows are in all respects satisfactory. Surely, if cows can do what many of the cows did whose records are set forth in this bulletin, namely, make considerable quantities of milk for several consecutive years on rations carrying approximately a pound or a pound and a half of digestible protein daily per 1,000 pounds live weight, one's faith is considerably shaken in the infallibility of some of the proposed standards, and certainly of the earlier ones, in so far as their digestible protein statements are concerned. The writer is frank to say that in his judgment the results secured in these long continued trials with the low and very low protein rations tend on the whole to substantiate the relatively low protein standard statements.

## VI. THE EFFECT ON THE QUALITY OF THE MILK FLOW OF RATIONS WIDELY DIVERGENT IN THEIR DIGESTIBLE PROTEIN CONTENTS

The very large number of records of cows fed one ration during one lactation and another during the following lactation furnish excellent data touching the age-old question of the effect of food on the quality of milk. No more testimony is needed; the case is closed; yet such a volume of data, covering so many, many years of bovine life, has not been offered before; and it seems worth presenting it, quite apart from the great tables A to F, inserted opposite page 64, where the point now under consideration is lost in the wilderness of figures. The table tells its own story.

| | Entire lactation | | | | | Winter feeding | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total solids | Fat | Casein and albumin | Milk sugar | Ash | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
| | % | % | % | % | % | % | % | % | % | % |
| Low protein ration | 14.37 | 5.14 | 3.65 | 4.82 | 0.75 | 13.71 | 4.62 | 3.60 | 4.78 | 0.74 |
| Medium protein ration | 14.58 | 5.27 | 3.74 | 4.81 | 0.75 | 13.79 | 4.66 | 3.60 | 4.82 | 0.72 |
| Higher ± lower | +0.21 | +0.13 | +0.09 | —0.01 | 0 | +0.08 | +0.04 | 0 | +0.04 | —0.02 |
| Low protein ration | 14.64 | 5.27 | 3.73 | 4.86 | 0.79 | 14.59 | 5.17 | 3.69 | 4.98 | 0.77 |
| High protein ration | 14.44 | 5.15 | 3.73 | 4.79 | 0.79 | 14.47 | 5.08 | 3.66 | 4.98 | 0.77 |
| Higher ± lower | —0.20 | —0.12 | 0 | —0.07 | 0 | —0.12 | —0.09 | —0.03 | 0 | 0 |
| Medium protein ration | 14.23 | 4.97 | 3.59 | 4.92 | 0.77 | 14.20 | 4.87 | 3.57 | 4.98 | 0.77 |
| High protein ration | 14.28 | 4.99 | 3.66 | 4.88 | 0.77 | 14.29 | 4.93 | 3.74 | 4.88 | 0.76 |
| Higher ± lower | +0.05 | +0.02 | +0.07 | —0.04 | 0 | +0.09 | +0.06 | +0.17 | —0.10 | —0.01 |
| Very low protein ration | 14.80 | 5.25 | 3.57 | 5.19 | 0.77 | 14.41 | 4.91 | 3.39 | 5.35 | 0.77 |
| Low protein ration | 14.47 | 5.14 | 3.44 | 5.19 | 0.72 | 14.13 | 4.81 | 3.31 | 5.29 | 0.72 |
| Higher ± lower | —0.33 | —0.11 | —0.13 | 0 | —0.05 | —0.28 | —0.10 | —0.08 | —0.06 | —0.05 |

Were the casein and albumin contents of the several milks affected by diverse feeding? Apparently to a slight extent. The grand averages of all records in tables A to F, inserted opposite page 64, were:

| Ration | Tables | Casein and albumin | Ratios |
|---|---|---|---|
| | | % | |
| High protein | A-D | 3.70 | 100 |
| Medium protein | A-D | 3.70 | 100 |
| Low protein | A-D | 3.65 | 98.6 |
| Low protein | E-F | 3.53 | 100 |
| Very low protein | E-F | 3.46 | 98 |

The figures are in the direction which would be expected theoretically. Cows relatively stinted on the one hand or somewhat liberally supplied on the other might well be expected slightly, at any rate, to tend to conserve or to be free with their usage of nitrogen in milk making. However, the changes are not large enough to warrant dogmatic statement, except that the immense amount of data contributing to their determination, involving as has been pointed out many thousands of analyses, tends to make any change, however small, somewhat impressive.

What was the effect of the frequent changes in rationing occurring during the short alternation trials upon the albuminoid contents of the milks? Total solids and fat contents were not affected, as is shown on pages 111 to 114; but it is conceivable that so profound a change as, for example, from the high to the low protein ration, might be reflected, for the time being at least, in the percentages of the nitrogenous milk constituents.

The grand averages appear below:

| Ration | Number of comparisons | Casein and albumin | Gains | Losses | Ration | Number of comparisons | Casein and albumin | Gains | Losses | Ration | Number of comparisons | Casein and albumin | Gains | Losses |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | % | | | | | % | | |
| From a relatively low to a relatively high protein ration | | | | | | | | | | | | | | |
| Low | 66 | 3.89 | .. | .. | Medium | 61 | 4.05 | .. | .. | Low | 92 | 3.94 | .. | .. |
| Medium | 66 | 4.02 | 47 | 14 | High | 61 | 4.12 | 35 | 21 | High | 92 | 4.03 | 61 | 25 |
| | | +0.13 | | | | | +0.07 | | | | | +0.09 | | |
| From a relatively high to a relatively low protein ration | | | | | | | | | | | | | | |
| Medium | 66 | 4.01 | .. | .. | High | 62 | 4.03 | .. | .. | High | 89 | 3.98 | .. | .. |
| Low | 66 | 3.98 | 24 | 35 | Medium | 62 | 4.12 | 39 | 18 | Low | 89 | 4.01 | 39 | 35 |
| | | —0.03 | | | | | +0.09 | | | | | +0.03 | | |

When the change was in the direction of feeding a more highly nitrogenous ration the percentage of albuminoids in the milk was increased in ⅔ of the instances, in ¼ diminished and in 1/12 unaffected. When the change was in the direction of feeding a less highly nitrogenous ration the percentage was increased in ½ of the instances, in ⅖ decreased and ⅛ unaffected. The average gain in the one instance was 0.10 percent; in the other 0.03 percent. Now it is to be expected that, after an interval of five weeks, the percentage of albuminoids ordinarily would be slightly increased; furthermore, that this increment would be identical on each side of the comparison, except in so far as the effect of ration change enters in to modify the result. Hence it seems safe to state as an approximate truth that in these short alternation trials when a relatively high protein ration replaced one of relatively low protein content, the average albuminoids percentage in the milk increased from 3.98 to 4.05. The ratios would then be 4.05 : 3.98 :: 100 : 98.3. This latter figure is closely comparable with the 98.6 shown above.

It seems reasonably clear from the testimony of these three trials, the low-medium-high digestible protein trials of 1906-1914, the very low-low digestible protein trials of 1914-1920 and the short alternation trials of 1906-1913, all of which tell the same tale, that to a slight extent the albuminoid percentage of milk is affected by changes in the digestible protein content of the ration and in a parallel direction.

## VII. THE ECONOMICS OF THE USE OF RATIONS WIDELY DIVERSE IN THEIR DIGESTIBLE PROTEIN CONTENTS

While it is realized, in view of profound changes from time to time in prices of roughages and concentrates, that attempts to apply money values to the results secured in these trials are of little value, notwithstanding, data were secured and are presented herewith.

The Boston Chamber of Commerce prices of No. 1 baled hay, stock hay, No. 1 and No. 2 clover hay were compiled, week by week, from the beginning of the trial in 1906 until the war broke out in 1914. Local prices were also secured month by month. Statements were collected annually from various parties in charge of cow test associations as to the values they were applying in their computation to hay at the barn. The ton prices of each of the several concentrates used in the grain rations were secured each month from two of the larger Vermont feed dealers. Weekly prices for "creamery extras" were received from the Boston Chamber of Commerce. Figures were available and secured for a considerable time during the war period, but conditions were then so abnormal that it seems best to use only the 1906-1914 figures. There were, of course, many fluctuations during this period. The following table sets forth averages; it also includes, as a matter of interest, the average monthly prices for 1921 as quoted in the markets of the State of New York and of Vermont, for the several concentrates used in the low, medium and high protein rations. It further includes 1921 data for the prices of hay and "creamery extras."

| | Boston Chamber of Commerce Weekly prices | | | Vermont local prices | | Two Vermont points—Ton prices | | | | | | Boston Chamber Commerce prices |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1 baled hay | No. 1 clover hay | No. 2 clover hay | No. 1 baled hay | Cow test association hay prices at barn | Wheat bran | Ground oats | Hominy feed | Gluten feed | Linseed meal | Cottonseed meal | Creamery extras |
| | ton | ton | ton | ton | ton | ton | ton | ton | ton | ton | ton | lb. |
| 1906...... | $17.76 | $15.50 | $12.70 | $18.00 | $.... | $24.50 | $29.50 | $26.50 | $30.00 | $33.00 | $33.50 | 30.4 cts. |
| 1907...... | 21.38 | 17.43 | 15.25 | 18.50 | .... | 27.04 | 35.71 | 28.46 | 30.71 | 32.71 | 31.83 | 28.3 " |
| 1908...... | 17.85 | 15.00 | 13.00 | 17.50 | 10.00 | 28.48 | 38.54 | 31.67 | 33.38 | 34.38 | 32.83 | 27.6 " |
| 1909...... | 18.06 | 14.75 | 13.05 | 17.00 | 10.00 | 28.80 | 37.38 | 32.38 | 32.83 | 36.21 | 35.58 | 29.5 " |
| 1910...... | 21.99 | 17.02 | 14.65 | 19.50 | 10.00 | 26.69 | 31.71 | 28.25 | 30.65 | 38.38 | 35.08 | 30.2 " |
| 1911...... | 22.72 | 15.31 | 13.19 | 20.00 | 10.00 | 28.31 | 31.79 | 29.02 | 29.15 | 39.57 | 32.19 | 27.2 " |
| 1912...... | 25.47 | 19.46 | 17.33 | 18.00 | 10.50 | 28.69 | 35.88 | 31.92 | 32.25 | 39.67 | 33.77 | 31.3 " |
| 1913...... | 21.20 | 17.39 | 14.39 | 17.00 | 10.75 | 25.50 | 30.71 | 28.96 | 30.63 | 33.29 | 35.08 | 31.8 " |
| 1914...... | 20.77 | 17.92 | 15.32 | 16.50 | 10.90 | 30.12 | 30.75 | 30.94 | 33.38 | 34.12 | 34.88 | 28.2 " |
| Ave....... | $20.83 | $16.64 | $14.32 | $17.95 | $10.25 | $27.72 | $34.30 | $30.09 | $31.44 | $36.18 | $33.81 | 29.4 " |
| 1906, 2 months' prices; 1914, 7 months' prices. | | | | | | | | | | | | |
| 1921...... | $28.80 | $23.50 | .... | $27.50 | $17.00* | $28.20 | $34.15 | $30.99 | $38.95 | $47.35 | $46.30 | 39.6 " |

*From four leading cow test associations. Data supplied through courtesy of H. E. Bremer, Supervisor Creamery Inspection and Cow Test Associations, Vermont Department of Agriculture. It is his judgment that the figure is probably an understatement.

It should be remembered that on the average baled hay is worth $2 more than is unbaled hay. Freight rates and carriage from farm to Burlington and to Boston should also be considered. Furthermore, No. 1 sales hay is not a cow hay but timothy hay. A careful consideration of these various figures led to the conclusion that a charge of $10.50 a ton for all hays fed at the barn was a reasonably accurate figure, a fair approximation to the truth. The average silage carried approximately 30 percent of the digestible dry matter content of the average hay. Thirty percent of $10.50 is $3.15. It seems reasonably safe to allow $3.25 a ton for silage, a material which, of course, has no specified market value. The average apple pomace contained almost the same digestible dry matter percentage as did the average silage, but, being a waste product, bought at from 50 cents to $1 a load, it seems fair, indeed, liberal, to estimate its money value at three-fourths of that of silage, i. e., $2.50. Soiling crops were fed in such small quantities that they cut almost no figure. Furthermore, they were very diverse in their nature and composition. It is doubtless safe to list them at $3. The three grain rations calculated on the pre-war basis: Low protein $30.28, medium protein $30.98, high protein $32.82. Pasture used to be estimated 20-30 years ago at 50 cents per cow per season. It would seem safer to list it now at least at 75 cents.

In this connection it is interesting to compare the 1921 costs of the four concentrate rations on the basis of the figures given in the above table as follows:

| | Cost | Digestible nutrients lbs. | Digestible protein lbs. | Cost per 100 lbs. digestible nutrients |
|---|---|---|---|---|
| Very low ....... | $30.50 | 77.8 | 8.3 | $1.96 |
| Low ............ | 30.68 | 70.4 | 10. | 2.18 |
| Medium ........ | 35.68 | 68.8 | 17.4 | 2.56 |
| High ........... | 40.92 | 72. | 24.1 | 2.84 |

It will be noted that whereas the "spread" in pre-war days between the cost of the low and high protein rations was only $2.54, it was $10.24 in 1921.

Using the figures at the bottom of tables A and C, B and D as units, and disregarding pasture usage and cost which were essentially identical in each instance, we have the following comparisons:

| | Cost of a day's food | Average daily yield | | | | Ratio food to production: One cent's worth food produced | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Milk | Total solids | Solids-not-fat | Fat | Milk | Total solids | Solids-not-fat | Fat |
| | cts. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| | | Entire year (365 days) | | | | | | | |
| Low protein... | 17.645 | 16.60 | 2.37 | 1.54 | 0.83 | 0.940 | 0.134 | 0.087 | 0.047 |
| Medium protein | 17.364 | 16.52 | 2.41 | 1.55 | 0.86 | 0.952 | 0.139 | 0.089 | 0.050 |
| High protein.. | 18.151 | 17.11 | 2.46 | 1.60 | 0.86 | 0.943 | 0.135 | 0.088 | 0.047 |
| | Winter feeding period (210 days) | | | | | | | | |
| Low protein... | 20.505 | 15.71 | 2.18 | 1.45 | 0.74 | 0.766 | 0.106 | 0.071 | 0.036 |
| Medium protein | 20.572 | 15.12 | 2.16 | 1.41 | 0.75 | 0.735 | 0.105 | 0.068 | 0.037 |
| High protein.. | 20.957 | 16.13 | 2.31 | 1.52 | 0.80 | 0.770 | 0.111 | 0.072 | 0.038 |

During the entire year the cows eating the medium ration made per unit cost the most product, gains being for milk and solids respectively 0.9 and 2.9 percents over the high and 1.3 and 3.6 percents over the low protein ration. During the winter months, however, the first (for the entire year) is last, although the last is not first. The high protein ration—in terms of dollars and cents—proved to be the more efficient milk maker, the gains for milk and solids being respectively, as compared with the low protein ration 0.5 and 4.5 percents, with the medium protein ration 4.5 and 5.4 percents. The reason why the medium protein ration did slightly better during the full year than its competitors is that the cows so fed ate a little less digestible dry matter than did their mates.

The writer once again reiterates his belief that these figures have very little value, points out that they are based on pre-war prices, and trusts that no one will take them too seriously. Obviously, from the economic point of view, the value of the three rations was pretty much the same when prices for roughages and concentrates were normal.

It should be understood that these rations were not constructed with a view of saving money or making cheap feeds; otherwise so costly a concentrate as ground oats would not have been used. The reasons dictating their choice are set forth on pages 28 to 29. The production value of units of digestible dry matter or digestible protein derived from different sources are sufficiently unlike so that it would have been quite possible for the writer to have formulated other rations carrying much the same contents of digestible protein and other nutrients, using other concentrates, rations which might have been less costly, which might, indeed, have been better milk makers. Such considerations tend still further to minimize the value of monetary calculations.

The testimony of both the long term and the short alternation trials is to the general effect that the differences in production values between the three rations, excluding the very low ration, were relatively minor, that is to say, they were within a 5 percent limit of extremes. It would seem, therefore, looked at from the economic standpoint, that the matter resolves itself into a study of relative prices.

If, therefore, at any time a concentrate ration which, when fed in conjunction with mixed hay and silage, furnished from 1.75 to 2 pounds of digestible protein, that is to say a ration which in its entirety might reasonably be looked upon as a medium protein ration, under the market conditions then prevailing is found to be less costly than is one carrying from, let us say 2.25 to 2.5 pounds digestible protein, that is to say a ration which might justifiably be held to be a high protein ration, so be it that essentially identical amounts of digestible nutrients are fed in each case; then under such conditions, the former is to be preferred to the latter, for the reason that production may be assumed to be likely to be much the same in either case. In 1906-1914, the concentrate portion of the former ration cost on an average $1.84 per ton less than did the concentrate portion of the latter ration; and in 1921, the former cost $5.24 less than did the latter. Consequently, the medium protein ration is to be prefered to the high protein ration under such circumstances, looked at from the point of view of economics.

Furthermore, if at any time a concentrate ration which, when fed in conjunction with mixed hay and silage, furnished from 1.35 to 1.5 pounds of digestible protein, that is to say a ration which might reasonably be looked upon as a low protein ration, under the market conditions then prevailing is found to cost less than 95 percent of what either a medium or high digestible protein ration as defined in the last paragraph would cost, so be it that essentially identical amounts of digestible nutrients are fed in each case; then under such conditions the low protein ration is to be preferred to either the medium or the high protein ration for the reason that while it might be expected to produce a somewhat smaller milk flow the shortage in production would be less than the diminution in cost. In 1906-1914, the concentrate portion of the low protein ration cost on an average 70 cents a ton less than did the concentrate portion of the medium and $2.54 less than the concentrate portion of the high protein ration; in 1921, these figures were respectively $5 and $10.24. Obviously under the conditions now (1921) obtaining the low protein ration is greatly to be preferred.

The statements in the two above paragraphs should be construed, however, as being limited by the following proviso, namely, that in each case the continued well-being of the animal is maintained, that the prolonged feeding of such a ration does not imperil the physical condition of the animals. In these trials extending over a long series of years, the low and medium protein rations were at least as good or if not better than the high protein ration in this respect (see page 62).

The plant food contents of the rations containing 2 and 2.5 pounds digestible protein are necessarily greater than of that containing but 1.5 pounds of digestible protein. The consumption of the home grown roughages by the cows of these several groups was essentially identical and the plant food contents of the same were naturally similarly identical. The concentrate consumption was also very much the same among the various groups in so far as their total and digestible dry matter contents were concerned; but the plant food contents in these grain rations were not identical, being respectively: low protein 2.11, 1.84 and 1.03; medium protein 3.18, 2.05 and 1.23; and high protein 4.24, 2.13 and 1.37 percents of nitrogen, phosphoric acid and potash. The medium protein ration carried a percent more nitrogen and 0.20 percent more each of phosphoric acid and potash than did the low protein grain ration and carried a percent less nitrogen and 0.10 percent less each of phosphoric acid and potash than did the high protein grain ration.

In the early days of these trials, at the prices then obtaining for plant food in commercial fertilizers, a 100 pound sack of the medium protein grain ration contained about 30 cents worth of plant food in excess of that contained in a similar sack of the low protein grain ration, and the high protein grain ration 60 cents worth in excess of the low and 30 cents worth in excess of the medium protein grain ration. During late war and post-war days these figures were nearly 75 cents, $1.50 and 75 cents.

During these 12½ years of experimental trials, there were brought onto the farm and fed to the cows approximately 140 tons of wheat bran, 80 tons of ground oats, 15 tons of gluten feed, 35 tons of hominy feed, 60 tons of cottonseed meal, 40 tons of linseed meal, 15 tons of corn and cob meal. These furnished in round figures 340 tons of dry matter, 250 tons of digestible dry matter and 75 tons of total and

55 tons of digestible protein. The 385 tons of concentrates contained, furthermore, approximately, 12 tons of nitrogen, 7½ tons phosphoric acid, 4½ tons of potash. In the early days of the trial, nitrogen cost delivered in Vermont about 30 cents a pound; phosphoric acid from 3 to 7 cents, according to its availability, and potash about 6½ cents. In 1919, these cost respectively about 70, 10 and 25 cents.

If it is assumed that these plant nutrients are worth as much as those furnished in commercial fertilizers—an assumption which perhaps is not fully justified—the plant food thus brought onto the University Farm was worth in the early days nearly $700 a year and in the later days more than $1,600 a year; that is to say, it would have cost these sums to have bought similar amounts of plant food in the form of commercial fertilizers in the manner in which commercial fertilizers are usually bought by farmers. Of course a relatively large amount of nitrogen as compared with phosphoric acid and potash was bought—doubtless more than was needed. Of course the cows took some toll. Of course some was sold from the farm in the form of cream and butter sales—little or no milk being sold. Of course losses occurred, due to fermentation, leaching and the like. But a large proportion of this plant food doubtless reached the soil.

In the early days of these trials, the concentrates—other than ground oats, which were relatively costly but which were used for a specific purpose—cost about $31 a ton. During the later war years and in those immediately succeeding the armistice they averaged to cost more than twice that sum. The average annual purchase at the outset amounted to more than $1,000; during later years it was nearly $2,500. If, however, one keeps in mind that when one buys concentrates, one purchases cow food and crop food with the same dollar, and if one is as careful with the crop food, i. e., the manure, as he is with the cow food, i. e., the feed, and if—a most important if—the cows are worthy of the name and are good producers, the return in increased human food, i. e., milk, and in increased cow food, i. e., crops grown on well manured soil, may be so satisfactory that the purchase of concentrates even at high prices may prove a profitable operation.

## VIII. THE NORMAL SHRINKAGE IN THE MILK FLOW DUE TO ADVANCING LACTATION

Among the items of information sought in these trials was the rate of normal shrinkage in milk yields and the relation of the various protein rations to such shrinkage. Records of 305 complete lactations are at hand for use in the comparison and are presented herewith:

| | Lactations | First month | Second month | Third month | Fourth month | Fifth month | Sixth month | Seventh month | Eighth month | Ninth month | Tenth month | Eleventh month | Twelfth month | Thirteenth month | Fourtenth month | Fifteenth month | Sixteenth month | Seventeenth month | Eighteenth month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Normal calving. (Average date of service after calving: Low 83 days, medium 74 days, high 90 days) | | | | | | | | | | | | | | | | | | | |
| Low protein ration..... | 74 | 100 | 94.2 | 86.7 | 76.8 | 71.5 | 65.0 | 61.0 | 54.6 | 48.0 | 39.8 | 34.5 | 30.9 | 29.7 | 24.9 | ... | ... | ... | ... |
| Medium protein ration.. | 58 | 100 | 94.6 | 87.8 | 75.3 | 69.7 | 64.8 | 58.6 | 52.8 | 45.6 | 35.4 | 27.1 | 22.0 | 20.4 | 19.9 | ... | ... | ... | ... |
| High protein ration.... | 68 | 100 | 95.0 | 88.9 | 79.0 | 73.9 | 70.3 | 61.5 | 55.8 | 48.4 | 40.8 | 34.8 | 29.2 | 29.1 | 29.6 | 28.6 | 23.6 | ... | ... |
| Average ........ | 200 | 100 | 94.6 | 88.0 | 76.8 | 71.7 | 66.5 | 60.5 | 54.3 | 47.3 | 38.7 | 32.6 | 27.1 | 26.1 | 24.8 | ... | ... | ... | ... |
| Percentage of previous month--average ... | .. | ... | 95 | 93 | 87 | 93 | 93 | 91 | 90 | 87 | 82 | 84 | 83 | ... | ... | ... | ... | ... | ... |
| Following abortion | | | | | | | | | | | | | | | | | | | |
| Low protein ration..... | 9 | 100 | 104.4 | 98.7 | 86.9 | 78.3 | 72.0 | 68.4 | 65.3 | 60.0 | 50.0 | 50.7 | ... | ... | ... | ... | ... | ... | ... |
| Medium protein ration.. | 11 | 100 | 95.4 | 87.9 | 76.0 | 65.2 | 62.2 | 58.7 | 60.2 | 48.5 | 42.3 | 38.2 | 36.8 | 37.4 | 39.3 | ... | ... | ... | ... |
| High protein ration.... | 8 | 100 | 101.0 | 94.5 | 85.3 | 80.8 | 74.4 | 69.7 | 70.5 | 68.6 | 71.0 | 67.0 | 61.1 | 53.1 | 57.1 | ... | ... | ... | ... |
| Average ........ | 28 | 100 | 100.3 | 93.8 | 82.7 | 74.5 | 69.5 | 65.3 | 65.3 | 59.3 | 54.1 | 52.1 | 49.5 | ... | ... | ... | ... | ... | ... |
| Percentage of previous month--average ... | .. | ... | 100 | 94 | 88 | 90 | 93 | 94 | 100 | 91 | 91 | 96 | 95 | ... | ... | ... | ... | ... | ... |
| Farrow cows | | | | | | | | | | | | | | | | | | | |
| Low protein ration..... | 22 | 100 | 97.6 | 93.0 | 82.0 | 79.8 | 75.4 | 68.3 | 64.1 | 60.3 | 56.0 | 52.1 | 49.5 | 46.9 | 41.9 | 36.0 | 26.6 | 31.0 | 31.3 |
| Medium protein ration.. | 28 | 100 | 91.3 | 82.0 | 70.5 | 65.9 | 61.5 | 55.2 | 52.1 | 45.8 | 44.7 | 44.2 | 43.3 | 40.9 | 35.6 | 33.9 | 33.3 | 26.0 | ... |
| High protein ration.... | 27 | 100 | 93.1 | 85.3 | 73.8 | 69.0 | 64.0 | 55.7 | 51.9 | 44.5 | 40.1 | 40.3 | 39.9 | 38.6 | 40.3 | 33.6 | 23.7 | 15.7 | ... |
| Average ........ | 77 | 100 | 94.0 | 86.8 | 75.4 | 71.5 | 67.2 | 59.8 | 56.0 | 50.1 | 46.7 | 45.5 | 43.9 | 42.1 | 39.3 | 34.5 | 27.7 | 23.5 | 24.2 |
| Percentage of previous month--average ... | .. | ... | 94 | 92 | 87 | 95 | 94 | 89 | 94 | 90 | 93 | 97 | 97 | 96 | 93 | 88 | ... | ... | ... |

This mass of data seems to warrant the following conclusions:

(1) During the first ninth months of the lactation of cows served approximately three months after normal calving, the tendency is for them to yield month by month approximately 9/10 of the milk flow of the preceding month, this figure being perhaps a bit low of truth during the first half of this period; and during the tenth to twelfth month to yield month by months 5/6 of the milk flow of the preceding month (based on 200 complete lactation records).

(2) During the year of lactation following abortion, the milk yields averaged month by month to be approximately 93 percent of the flow of the preceding month (based on 28 complete lactation records; 18 cows served an average of 98 days after abortion; 10 farrow).

(3) During 15 months' lactation following calving, the milk flow of farrow cows averaged month by month to be approximately 13/14 of the yield of the preceding month (based on 77 lactation records).

In the Ninth Report of this Station—pages 165-166—appear tables setting forth the records of 94 lactations of spring and fall cows. No statement occurs as to whether or not the cows were kept farrow or were served. However, in view of the fact that during the tenth month following calving the average cow was giving 52 percent of the yield of her first month, it would seem that many of the cows must have been farrow or bred when relatively far along in lactation. The shrinkage factor is 13/14, as in the case of the 77 farrow cows cited.

Not much can be said as to the relation of the different rations to the retardation of the shrinkage in milk flow. The many normal calving and service records displayed in the early pages of this bulletin indicate a slight preponderance in favor of the high protein ration, whereas the farrow cows fed the low protein ration shrank very much more slowly than did those fed the other two rations. It is at least a moot point whether bovine individuality, rather than diversity of feeding practise, is not responsible for such variation as was observed.

## IX. THE DEPRESSIVE EFFECT OF ABORTION UPON THE MILK FLOW

Abortion occurred all too frequently. No less than 28 of the 305 lactations followed this mishap. And the nature of the trials was such that the damage thus wrought exceeded 9 percent, i. e., 305:28. However, since this malady did afflict the herd, one may as well make use of the misfortune. Ample data are at hand enabling another measurement of the direct loss in milk yield due to abortion by comparing milk yields and qualities in adjacent lactations in which normal calving and abortion occurred.

Twenty-one cows were concerned. In one instance, Nesbit, a very inferior animal, kept only because the exigencies of the maintenance trials necessitated it, almost as much milk was given following abortion as in one adjacent normal lactation and more than half as much again as in another. However, its fat content was very greatly depressed, an unusual occurrence. In another instance, Altje, a heavy milking grade Holstein, did just as well following abortion as she did in the two lactations preceding and following this mishap; and the quality of her milk was not altered. However, she had had a long rest from milk making prior to abortion, which may account for the anomalous result. The other 19 cows made from 7 to 46 percent less milk after abortion than they did after adjacent normal calvings, the same number of weeks being listed in each instance. The average shortage for 21 cows was 22 percent. It should be borne in mind in this connection that every cow which aborted had necessarily been served, but that following abortion, only two-thirds of them were served. This causes a slight advantage to accrue to the abortion figures, which theoretically, should on this account be slightly increased. This means, in other words, that the 22 percent average shortage in milk flow to a slight extent is an understatement. Inevitably the two sides of the equation could not be made uniform.

A comparison of divergences from normal in the quality of the milk flow following abortion indicated that the trend was as follows:

Total solids ..............increased 52%; decreased 33%
Fat ......................increased 62%; decreased 29%
Casein and albumin........increased 67%; decreased 29%
Milk sugar ...............increased 19%; decreased 57%

The average result, including the anomalous Nesbit data, indicates that, following abortion, total solids, fat and casein and albumin increased each approximately 0.20 percent and milk sugar decreased approximately 0.25 percent. These results are in line with those heretofore reported at this Station.[1]

There appeared to be no relation between the nature of the grain ration and abortion; that is to say, this misfortune seemed to be in no ways related to the feeding of different amounts of protein.

In this connection, reference may be made to the frequent failure to breed, to sterility. This seriously affected the conduct of the protein and maintenance (bulletin 226) trials. A careful study of the records did not lead the writer to conclude that any necessary correlation existed between sterility on the one hand and the use of any particular ration upon the other.

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[1] Vt. Sta. Rpts. 6, pp. 114-119 (1892); 9, pp. 184-186 (1895).

## X. THE EFFECT OF ABRUPT CHANGES IN RATIONING UPON THE MILK FLOW

Necessarily many changes in rations occurred during the course of the short alternation trials (1906-1913). At five-week intervals the cows were shifted abruptly from one ration to another, from the low protein to the high protein, for example. Very few changes were made involving material alterations in the intake of total dry matter or digestible nutrients, but the digestible protein intakes were considerably altered, and altered abruptly, being increased when the change was made from as little as ¼ to as much as ⅔ and decreased when the change was made for from as little as ⅕ to as much as ⅖.

The results secured by comparing 394 records of the milk flows of adjacent weeks preceding and following abrupt and decided changes in the digestible protein intakes, are shown in the subjoined table.

| Protein ration | Number of record | One week's milk flow lbs. | Number of records | | |
|---|---|---|---|---|---|
| | | | Gains | Losses | No change |
| Low ............ | 65 | 103.7 | | | |
| Medium ........ | 65 | 104.1 | | | |
| | | +0.4 | 26 | 31 | 8 |
| Percentage ±.... | | +0.4% | 40% | 48% | |
| Medium ........ | 65 | 107.4 | | | |
| Low ............ | 65 | 105.1 | | | |
| | | —2.3 | 14 | 43 | 9 |
| Percentage ±.... | | —2.1% | 22% | 66% | |
| Medium ........ | 56 | 107.3 | | | |
| High ........... | 56 | 107.1 | | | |
| | | —0.2 | 22 | 21 | 13 |
| Percentage ±.... | | —0.2% | 39% | 38% | |
| High ........... | 56 | 113.3 | | | |
| Medium ........ | 56 | 108.5 | | | |
| | | —4.8 | 8 | 40 | 8 |
| Percentage ±.... | | —4.3% | 14% | 71% | |
| Low ............ | 76 | 112.8 | | | |
| High ........... | 76 | 114.7 | | | |
| | | +1.9 | 50 | 18 | 8 |
| Percentage ±.... | | +1.7% | 66% | 24% | |

| Protein ration | Number of record | One week's milk flow | Number of records<br>Gains | Losses | No change |
|---|---|---|---|---|---|
| | | lbs. | | | |
| High ........... | 76 | 118.8 | | | |
| Low ............ | 76 | 115.4 | | | |
| | | —3.4 | 14 | 55 | 7 |
| Percentage ±.... | | —2.8% | 18% | 72% | |

It seems quite clear:

(1) That when a ration carrying a relatively high digestible protein content replaced one of a relatively low digestible protein content, the replacement being abrupt, the total dry matter and total digestible nutrients contents of each being essentially identical, an undiminished milk flow was maintained during the initial week in which the new ration was fed, whereas the usual shrinkage when no change in rationing occurs approximates two percent; and that to the extent of one percent or more the milk flows were increased in ½ and decreased in ⅜ of the comparisons, whereas in ⅐ of the comparisons no variation occurred.

(2) That when a ration carrying a relatively low digestible protein content replaced one of a relatively high digestible protein content, the replacement being abrupt, the total dry matter and total digestible nutrient contents of each being essentially identical, the milk flow shrank as much or more than was to have been expected had no change in rationing occurred, to an extent, on the average, of fully one percent over normal shrinkage; and that to the extent of one percent or more the milk flows were decreased in ⅔ and increased in ⅕ of the cases, whereas in ⅛ of the comparisons no variation occurred.

(3) That, apparently, an increased digestible protein intake tended slightly to retard the shrinkage in the milk flow, at any rate at the outset and to act slightly as a milk stimulus.

No effect whatsoever was noted in respect to changes in the quality of the milks, following immediately upon ration replacement, the average total solid and fat contents being identical.

It is well understood that abrupt and profound changes in rationing, such, for example, as from a full supply to a half ration of digestible nutrients, may decidedly affect both the quantity and the quality of the milk flow. This has been abundantly proven, never more convincingly than by Eckles in his studies of under-nutrition and over-nutrition of dairy cows cited elsewhere (pages 177-183). Apparently abrupt changes in the digestible protein intakes are not as likely to be reflected in the milk yield, provided no material change is made in the digestible nutrient intake.

## XI. SUMMARY

Attempting now in summation to answer the twelve questions stated at the opening of the bulletin, the writer ventures to express the following opinions, based on the data presented in the foregoing pages. In order more clearly to connect question and answer, the former are repeated.

1. *What effect was wrought upon the milk flow by the long continued use of rations carrying either very low, or relatively low, or medium, or high digestible protein contents?*

The results which were secured in the long term trials seem to justify the statement that for some years at least a ration carrying a pound of digestible protein a day per 1,000 pounds live weight may serve the purposes of a not over heavy milking cow, enabling her to yield a reasonable, though obviously not a large, amount of milk. With a full assurance of certainty this can be said of the use of a ration carrying 1.5 pounds of digestible protein per day per 1,000 pounds live weight. A ration carrying 2 pounds of digestible protein a day per 1,000 pounds of live weight may enable a cow to yield a little more but not much more milk than the two rations above indicated. It is quite unnecessary for milk making purposes to increase the digestible protein content of the ration to 2.5 pounds per day per 1,000 pounds of live weight.

These statements are predicated upon the results attained in these long time trials in which cows, largely grade Jerseys, made average daily records approximately as follows:

| Ration | During 7 months of barn feeding | | | | | | For the entire year | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live weight | Total digestible nutrients | Digestible protein | Milk | Total solids | Fat | Live weight | Total digestible nutrients | Digestible protein | Milk | Total solids | Fat |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Very low | 831 | 9.35 | 0.75 | 14.9 | 2.21 | 0.79 | 837 | 13.6 | 1.08 | 17.6 | 2.62 | 0.91 |
| Low | 872 | 10.15 | 1.02 | 16.5 | 2.33 | 0.80 | 869 | 13.5 | 1.41 | 19. | 2.71 | 0.92 |
| Low | 894 | 11.8 | 1.26 | 17. | 2.41 | 0.84 | 914 | 14.1 | 1.47 | 16. | 2.26 | 0.78 |
| Medium | 906 | 11.7 | 1.64 | 16.4 | 2.38 | 0.85 | 941 | 14.1 | 1.91 | 15.8 | 2.24 | 0.78 |
| High | 896 | 12. | 2.09 | 17.4 | 2.47 | 0.86 | 898 | 14.6 | 2.41 | 17.1 | 2.44 | 0.84 |

The comparisons, it should be remembered, do not cross the space between the two horizontal lines of figures representing the low ration.

2. *What effect was wrought upon the physical condition and health of the cows which were fed on a uniform diet for a long series of years? Was either a relatively low digestible protein content on the one hand or a relatively high digestible protein content on the other inimical to their continued well-being?*

. The cows which were continuously fed for upwards of 4½ years on the very low digestible protein ration, the intake being barely a pound daily per 1,000 pounds live weight, were not injured in respect to their physical condition, in so far as the same could be determined by careful survey. This general statement holds for each of the 10 cows thus continuously fed. Neither is there definite information in hand to warrant the assertion that the continued feeding of the high protein ration, 2.5 pounds digestible protein a day per 1,000 pounds live weight, was in any respect injurious. Yet it is interesting to note, though probably in nowise significant that, speaking broadly, the cows to which this ration was fed tended to drop out earlier, to last a shorter time than those fed the medium protein (2 pounds) or low protein (1.5 pounds) rations. The writer lays no stress upon this fact—but it is a fact.

3. *What relation did rations carrying very low, or low, or medium, or high digestible protein contents bear to changes in the body weights of milking cows?*

The cows which were continuously fed for upward of 4½ years on the very low digestible protein ration, tended to lose live weight, averaging an 8 percent loss, maintaining their milk yields at the expense of body weight, their losses, however, being not sufficient to induce emaciation or unthriftiness. The cows fed the low and the medium digestible protein rations tended to gain in body weight until approximately 10 years of age. The cows which were fed the high protein ration put on relatively little live weight and tended as a whole slightly to lose in weight after the seventh year.

4. *What were the immediate effects upon the milk flow of rations carrying either very low, low, medium or high digestible protein contents, as determined by means of trials of short duration?*

The results which were secured in the short alternation trials seem to justify the statement that the high protein ration averaged to make

3.5 percent more product than the low protein, and 2 percent more than the medium protein ration, and that the latter made 2.5 percent more than the low protein ration.

5. *Were the results obtained in feeding trials conducted for many months or years comparable with those secured in trials of shorter duration?*

On the whole the results secured in short alternation trials may be expected to be reasonably parallel to those afforded by long-time experiments, provided the former are carefully planned, well executed and the number of animals used is ample.

6. *What was the relation between the digestible nutrients in the food and those accounted for in maintenance and milk flow, when rations were fed differing widely in their digestible protein contents?*

The digestible protein utilization in milk making varies profoundly with ration changes in respect to this nutrient. Carbohydrate utilization similarly varies but inversely to and less profoundly than protein. In several instances, using the old time 0.7 pound digestible protein maintenance allowance, recovery exceeded 100 percent. Protein recovery was essentially identical for thin and for rich milking cows.

7. *What may be said, in the light of the results in these trials secured, touching existing feeding standards?*

Existing feeding standards are plentiful in number and some of them are reasonably satisfactory. The outcome of these trials tends to substantiate those standards which suggest somewhat lower digestible protein needs than were set forth a generation ago; and the vast amount of data in bulletin 226—dealing with "The Maintenance of Dairy Cattle" likewise tends to uphold this statement.

8. *Was the quality of the milk flow altered when rations were fed which contained widely divergent digestible protein contents?*

The total solid and fat contents of the several milks were unaffected by the changes in rationing, but to a slight extent their albuminoid contents were changed in a direction parallel to the increase or decrease in the protein content of the ration.

9. *What can be said touching the economics of milk and butter production when rations were fed which were decidedly unlike in their digestible protein contents?*

The vageries of the American feed markets are such that it is quite impossible dogmatically to assert that any one of the four rations fed, or any other constructed with a view of furnishing equivalent amounts of digestible protein and total digestible nutrients, necessarily is always to be preferred—viewed from its standpoint of economics. However, as things were in pre-war days, there was but little to choose between them, whereas nowadays the high protein ration is inordinately costly as compared with the medium or low protein rations. This is doubtless a reflex of the abundant corn crop of 1921 and its consequent low price. However, it should always be borne in mind that, other things being equal—they are far from being equal at present (1921)—so be it prices are not materially unlike, a more nitrogenous ration is to be preferred because of its increased content of plant food.

10. *What is the normal shrinkage in bovine milk flow?*

The testimony which was afforded by 305 complete lactations indicated that cows bred to calve 12 to 14 months after calving tend to give month by month 9/10 of the yield of the preceding month, for nine months and 5/6 of the yield of the preceding month during the remainder of their lactation. Cows which have aborted or which remain farrow tend to give month by month 13/14 of the yield of the preceding month. These factors are closely similar to those heretofore published. This large amount of data simply "adds to the present stock of information"; which was all that it was expected it would do.

11. *To what extent is the milk flow directly affected by abortion?*

As a result of abortion (28 cases having occurred) the average milk flow was decreased for 1/4 to 1/5 and the total solids, fat and albuminoid percentages increased about 0.20 percent.

12. *What effect upon milk flow is wrought by abrupt changes in rationing?*

Based upon the comparison of 394 instances of abrupt changes in rationing, the statement seems warranted that, provided no material alteration occurs in the digestible nutrient intake, abrupt changes in the digestible protein intake are not likely to be reflected in the milk yields.

## XII. THE LITERATURE OF PROTEIN USAGE BY DAIRY COWS

The literature of protein usage by dairy cattle is voluminous. The question has been studied from the early days of scientific cattle feeding. Armsby's "Manual of Cattle Feeding" (1880), represents the first connected and systematic attempt to present the results of European experience to American readers. It cites Wolff's (1868) studies and Kühn's (1877) more extensive trials. Armsby states that Kühn's results "show plainly that a liberal supply of protein in the food favors an abundant production of milk; and that this conclusion is confirmed by a large number of other investigators."

Since 1880, and particularly since the establishment of the American Experiment Station system, much work has been done. It has seemed worth while to attempt to collate the results and, consequently, with the Experiment Station Record as a guide, the writer (J. L. H.) has tried to review the published statements concerning feding, trials with dairy cattle from 1888 to the May, 1921, issue E. S. R. In so far as possible he has sought access to the original publications. This he was able to do with all American and Canadian material and with some from foreign countries. Most of the foreign matter was inaccessible and much of it unreadable—by him—even if accessible. In these instances he has relied upon the E. S. R. abstracts.

The review does not pretend to be complete. Undoubtedly publications have been overlooked which should have been included.

### THE GOATS

No statement whatsover is made concerning many hundreds of trials, the results of which were carefully surveyed by the writer. Sometimes no analyses of fodders and feeds were made. Sometimes the milks were not analyzed. In some instances conditions other than feed changes were not controlled, indeed the existence and relationship of some such are often naïvely confessed. In one instance, the title of the 40-page bulletin included the words "milk production," yet the word "milk" does not occur in the text from beginning to end. In some cases fodder and feed analyses are given without digestion coefficients and without attempt to indicate digestible nutrient consumption. And in multitudinous cases the feeding periods have been too brief to afford valid results or in other respects the conduct of the trial has been inadequate.

In a few instances the writer has been forced, using the data presented in the publication under review, as it were to reverse the findings as printed. He has been very loath to do this and has studied the data from every angle with all sorts of cross checks, so as to be certain that he did not misinterpret the findings as stated.

In one case the asserted outcome was at utter variance with the published data, due to palpable errors in addition, multiplication and division.

Another flagrant, indeed an almost amusing, instance of non-coordination of fact and finding may be cited. In a certain publication the results are expressed in terms of gallons of milk and pounds of butter, as follows: Ration A, 1,720 gallons and 558 pounds; ration B, 1,322 gallons and 397 pounds; and yet the statement is made that "it is quite fair to conclude that the results so apparently favorable to (B) were due to the fact that (A) was badly balanced." The apparently favorable results were purely financial, purely temporary; and because the roughage in (B) was arbitrarily rated at a lower cost than that in (A) the fact that A made 30 percent more milk and 40 percent more butter was concealed in the text though set forth in the tabulation. Indeed A's greater productive power was specifically decried; and this after the American experiment station system had been in operation for more than a quarter of a century.

Eight fodders and feeds were used in a certain trial. Three were analyzed, but no clue is furnished as to the analyses of five; yet the digestible nutrients of each are indicated. However, if average analyses and the usual digestive coefficients were employed, no such figures published as digestible nutrients are possible. If, on the other hand, analyses were made and the usual digestive coefficients used, the like of such fodders and feeds never grew on sea or land. And, to cap the climax, the rations are carefully calculated to the third decimal and the declared outcome is at variance with the data.

One publication proved particularly interesting. It sets forth the outcome of an eight-weeks trial with 18 cows fed in two-week periods. The results, of course, were worthless. However, the author used over 30,000 words, piled up fully 12,000 figures and constructed many, many charts in order to tell his tale. "And they think that they shall be heard for their much speaking." The Experiment Station Record summation is mercifully brief, consisting of barely 500 words.

In this connection the writer may say that he does not cast his stone, being himself without sin; for much of his own earlier work is justly open to criticism, containing errors due to ignorance, to inexperience and, worse, to carelessness.

### THE METHOD OF PRESENTATION

The method of presenting this review has proved a perplexing matter. There appears to be no necessary and logical order. It seemed best at the outset to proceed chronologically, completing the reference to a given author, once for all. However, later on it was determined to attempt to segregate the abstracts on the basis of their more or less direct relationship to the protein problem; and, consequently, they have been assembled, doubtless not without error in listing, as indicated below, including under the category of "miscellaneous" abstracts of many very important trials which, however, did not readily classify.

More space is allotted to three abstracts than to others, namely: the results secured at this Station from 1896 to 1906; Haecker's important contribution from the Minnesota Station; and Eckles notable piece of work while at the Missouri Station, dealing with sub-normal and super-noormal nutrition. The Vermont work covered over 2,000 "records" or "periods" of feeding and both on account of its volume and because this bulletin is a Vermont issue seems worthy this special consideration. The second represents many years of study and, consequently, deserves particular attention; but more especially is it to be noted because of the overemphasis—in the writer's (J. L. H.) judgment—which has been laid upon a certain phase of the trials (see page 175). The third epitomizes the results of a prolonged study which, as a matter of fact, has no marked relation to the protein problem, but which is of so fundamental a character as to justify its inclusion. The material, therefore, is listed as follows:

1. Abstracts relating to digestible protein studies *per se.* (Pages 149-164.)
2. Abstracts relating to the effect of diverse rations upon the quality of milk. (Page 164.)
3. Abstracts dealing with trials in which unusually heavy feeding obtained. (Pages 164-166.)
4. Abstracts relating to the Vermont Station feeding trials, 1896-1906 (Hills). (Pages 166-173.)
5. Abstracts relating to the Minnesota feeding trials (1900-1914), (Haecker). (Pages 173-177.)
6. Abstracts relating to the Missouri sub- and super-normal feeding trials (Eckles). (Pages 177-183.)
7. Abstracts relating to feeding trials of a miscellaneous character. (Pages 183-195.)
8. Quotations from Kellner, Armsby and Woll. (Pages 195-198.)

### 1. ABSTRACTS RELATING TO DIGESTIBLE PROTEIN STUDIES *per se*

Jordan (1885) fed three cows for 12 weeks, by the reversal system, on rations of 18 pounds timothy hay and five pounds cornmeal with two pounds cottonseed meal, replacing an equal amount of cornmeal during two periods. The rations furnished 0.9 and 1.5 pounds of digestible protein, 12 and 11.6 pounds of digestible carbohydrates and fat (x 2¼) and their nutritive ratios were 1:13.8 and 1:7.9. When cornmeal replaced cottonseed meal the yield dropped 20 percent. The effects on fat percentages were discordant. Body weights were not affected.

He repeated the trials using four cows, two fed clover hay and two timothy hay, in other respects duplicating the earlier trial. The nutrients furnished were not calculated. One pound more of grain was fed to the cows than in the previous trial, the figures for the cows fed timothy hay, being approximately 1.0 and 1.8 pounds digestible protein, 12.9. and 12.5 pounds of digestible carbohydrates and fat (x 2¼) and nutritive ratios 1:12.9 and 1:7. The clover hay-fed cows ate somewhat more digestible protein than those fed timothy hay and the nutritive ratios were somewhat narrower in each instance. The timothy hay-fed cows shrunk 20 percent in milk and the clover hay ones 7 percent when cornmeal replaced cottonseed meal. The fat percentages were not affected noticeably, though the timothy hay-fed cows gave slightly richer milk on cornmeal. *Me. Sta. Rpts. 2, pp. 65-72 (1885); 3, pp. 84-89 (1886).*

Woll (1894) fed 12 cows for 12 weeks on hay, silage, wheat middlings as a basal ration and either 4.1 pounds of linseed meal, of corn meal or of bran. No analyses of the several constituents of the rations were made. However, using average compositions and digestion coefficients, it was estimated that the three rations contained of total organic matter, digestible protein, digestible carbohydrates and fat (x 2¼), respectively, 25.5, 25.1 and 25.6 pounds, 2.6, 1.7 and 2 pounds, 15.7, 16.4 and 15.9 pounds, and that nutritive ratios were 1:6, 1:9.5 and 1:8.1. The cows got plenty to eat in all cases.

Body weights were somewhat increased on the latter two rations. No material advantage appeared in respect to milk yield in favor of either ration, such little as did appear favoring the linseed meal ration. The fat percentage of the milk made on the corn ration was slightly less than that made when linseed meal or bran were fed. *Wis. Sta. Rpt. 11, pp. 113-130 (1894); Abstr. E. S. R. 8, pp. 335-336 (1896).*

Carlyle and Woll (1903) discuss the protein requirements of dairy cows, following a review of a five-years' trial of low, medium and high protein feeding of 38 cows in which 1,000-pound animals received on the average respectively 1.52, 1.84 and 2.23 pounds digestible protein. Only 10 cows ate more than 2 pounds daily; yet 25 produced over 300 pounds of fat yearly. The "best" producers, making approximately 8,500 pounds of milk and 350 pounds of fat, ate during the winter 25.3 pounds total dry matter, 2.05 pounds digestible protein, 15.2 pounds digestible carbohydrates and fat (x 2¼)—nutritive ratios averaging 1:7.4. The relatively low producing cows, giving approximately 6,100 pounds of milk and 290 pounds fat, ate on the average 21.1, 1.56 and 12.2 pounds, the nutritive ratios averaging 1:7.8.

After referring to the Wolff and the Wolff-Lehmann protein feeding standards (2.5 pounds digestible protein per 1,000-pound cow in full milk; 1.6 to 3.3 pounds per 1,000-pound cows giving from 11 to 27.6 pounds of milk) they affirm their belief that "under average American conditions a protein supply of 2.2 pounds per head per day is sufficient." They point out that "the average amount of protein supplied in the dairy rations of all the cows (in the Wisconsin Station herd) during four years had been 1.85 pounds * * *; (that) a number of the cows received less than 1.5 pounds digestible protein per day calculated on 1,000 pounds live weight on the average of all winter periods and produced over 300 pounds butter fat annually." They cite the record of a cow averaging during four years 1,002 pounds live weight that produced 343 pounds of butter fat yearly and received 1.48 pounds of digestible protein in her daily ration during the winter periods. They state they "are inclined to believe that only heavy-producing cows will give economical returns for a supply of more than two pounds of digestible protein per day * * * and in the majority of instances, with average good dairy cows, a supply somewhat less than this will be found most economical." *Wis. Sta. Bul. 102, pp. 83-84 (1903); Abstr. E. S. R. 15, pp. 502-504 (1904).*

Woll and Humphrey (1910) report concerning nine years' feeding in the University of Wisconsin herds, wherein during two periods of three years each, rations of a medium digestible protein content—nutritive ratios 1:7 or wider—were fed, whereas in the intermediate 3-year period somewhat narrower rations—nutritive ratios approximating 1:6 were used. Farm grown and commercial grains were used in both instances, but in the latter case relatively more oil meal, distillers' and brewers' dried grains were fed. Roughages were reasonably constant as to their character, being in the main mixed clover and timothy hay and corn silage. The average data may be concisely expressed as follows:

| Years | Cows | From calving | In milk | Live weight | Total dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Fat | Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | days | days | lbs. | lbs. | lbs. | lbs. | | lbs. | % | lbs. |
| 1900-03 & 1906-09 | 24 | 164 | 164 | 1060 | 21.9 | 1.76 | 13.1 | 1:7.4 | 21.1 | 4.27 | 0.90 |
| 1903-06 ........ | 31 | 222 | 151 | 1086 | 21 | 1.97 | 12.2 | 1:6.2 | 18.9 | 4.34 | 0.82 |

Of course cows came and cows went, 27 animals contributing to from 3- to 8-year records. The authors conclude that in these trials rations carrying medium protein contents (*i. e.*, 1:7.4 nutritive ratio) proved on the whole more economical and more effective, both absolutely and relatively, than rations carrying relatively high protein contents approaching the German standard rations (1:6.2). No ill effects of either ration on animal well-being was noted, nor was there any material effect exerted upon body weights, although some slight tendency was observed towards the putting on of weight during the feeding of the medium protein ration. Yet, notwithstanding, the authors stress the need of liberal protein supplies in the production of large milk flows and state that in these trials—speaking broadly—"the larger the production, the more feed the cows ate and the narrower the nutritive ratio became."

A significant feature of the outcome is that the medium protein rations were composed of farm grown feeds, supplemented with mill feeds and only small amounts of high protein concentrates. *Wis. Sta. Rsch. Bul. 13 (1910)*; also *Bul. 200 (1910)*; *Abstr. E. S. R. 25, pp. 79-80 (1911)*.

Woll, Humphrey and Osterhaus (1914) fed during three summers 24, 26 and 22 cows for 84, 70 and 91 days by the group method, comparing in each instance hay and a grain mixture supplemented by either silage or soiling crops. The latter consisted of: clover, peas and oats, oats, sweet corn and corn, peas and oats. All the cows had access to pasture limited in area and amount. The grain fed consisted of distillers' dried grains, bran, oats and corn meal. The silage-fed cows ate, above their pasture feeding, from 12.1 to 15.7 pounds of total dry matter, from 1.1 to 1.7 pounds of digestible protein, from 7.8 to 9.4 pounds of digestible carbohydrates and fat (x 2¼) and nutritive ratios ranged from 1:5.6 to 1:8.6. The cows fed soiling crops ate, over and above pasture, 11.4 to 15.3 pounds of total dry matter, 1.2 to 1.8 pounds of digestible protein, 7.1 to 9 pounds of digestible carbohydrates and fat (x 2¼) and nutritive ratios ranged from 1:5 to 1:7.2.

The outcome of the three years' work was identical, the average daily milk, solid and fat yields being 22.5 and 22.6, 2.97 and 2.96, 0.94 and 0.92 pounds. Live weights were not affected. The silage rations were the wider, 1:6.9 and 1:5.8, and furnished 3 percent more total dry matter. *Wis. Sta. Bul. 235 (1914)*; *Abstr. E. S. R. 30, pp. 874-875 (1914)*.

Waters and Hess (1895) studied the effect of rations of varying nutritive ratios upon production, feeding nine cows for 120 days. Corn stover was fed as roughage, together with chopped wheat, with either gluten feed and cottonseed or linseed meals as concentrates. No analyses were made of fodders or feeds.

The production records are remarkable in respect to their extreme uniformity. Every one of these nine cows without a single exception increased her total solid and fat percentages on passing from the gluten to the cottonseed ration; again on passing from cottonseed to linseed; and made less milk and lowered her solids and, with one exception, fat percentages in passing from linseed back to gluten again; 54 records with but a single break, a conspicuous result. Furthermore, every cow's milk contained more nitrogen when fed cottonseed than when fed gluten; 7 out of 9 more when fed linseed than when fed cottonseed, an eighth being identical and the ninth falling very little; and 6 out of 9 less when fed gluten at the close of the trial than when fed linseed, with two identical and only one falling slightly; or 23 out of 27 records in a definite direction, a total of

76 out of 81, a most remarkable result. The average daily yields for milk solids and fat were: 16.4, 16.2, 15.1 and 13.7 pounds; 2.15, 2.27, 2.19 and 1.92 pounds; 0.69, 0.79, 0.80 and 0.69 pounds; and the average solids and fat percentages were: 13.11, 14.01, 14.49, 1402, 4.09, 4.74, 5.13, 4.87.

All the cows were fed for 30 days on the gluten, for the next 30 on the cottonseed, the next 30 on the linseed and the last 30 on the gluten ration again. No attempt was made to separate the periods into preliminary and experimental portions, the entire mass being calculated regardless of the violent changes. Allowing for normal shrinkage as between the first and fourth periods and comparing with the results of the second and third, the following comparisons may be made:

| | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| Gluten feed... | 11.6 | 1.5 | 10.1 | 6.7 | 15.5 | 13.40 | 4.35 | 2.08 | 0.69 |
| Cottonseed meal | 12.7 | 2.6 | 10.1 | 3.9 | 16.2 | 14.00 | 4.75 | 2.27 | 0.79 |
| Cottonseed meal | | | | | | | | | |
| ± gluten... | + 1.1 | + 1.1 | 0. | .. | + 0.7 | + 0.60 | + 0.40 | + 0.19 | + 0.10 |
| ± percent.. | +10. | +73. | 0. | .. | + 5. | + 4. | + 9. | + 9. | +14. |
| Gluten feed... | 11.6 | 1.5 | 10.1 | 6.7 | 14.6 | 13.70 | 4.60 | 2.00 | 0.69 |
| Linseed meal. | 12.8 | 2.4 | 10.4 | 4.4 | 15.2 | 14.50 | 5.15 | 2.20 | 0.80 |
| Linseed meal | | | | | | | | | |
| ± gluten... | + 1.2 | + 0.9 | + 0.3 | .. | + 0.6 | + 0.80 | + 0.55 | + 0.20 | + 0.11 |
| ± percent.. | +10. | +60. | + 3. | .. | + 4. | + 6. | +12. | +10. | +17. |

The food intakes during the cottonseed and linseed meal periods were 10 percent greater and the digestible protein intakes two-thirds greater. It took about 5 percent more digestible food to make a pound of milk from the more liberal rations but about 5 percent less to make a pound of fat because of the profound changes in the quality of the milk. *Pa. Sta. Rpt. for 1895, pp. 56-74; Abstr. E. S. R. 8, pp. 823-825 (1896).*

Atwater and Phelps (1897) discussed the relation of nitrogenous rations to the feeding of dairy cows and reviewed testimony presented by several American stations touching this matter. The senior author was a pioneer in American station work, especially along nutritional lines. No one was better entitled to express an opinion concerning nutrition a quarter of a century ago. They gave it as their judgment that the weight of experimental evidence cited clearly indicated that liberal protein consumption and narrow rations tend to increase the milk flow and to retard the shrinkage due to advancing lactation and that to some slight extent they may tend to increase the total solid and fat percentages, bovine individuality being the controlling factor in this latter respect. *Conn. (Storrs) Sta. Rpt. 10, pp. 98-112 (1897); Abstr. E. S. R. 10, pp. 684-685 (1898).*

Kellner (1907) discusses metabolism studies wherein the determination of the minimum amount of food protein requisite in milk production was sought. In these trials of rations high in energy values but carrying only enough nitrogen to equal that voided in the excretory products and appearing in the milk, the cows continued for a long time to yield a milk of good quality, the entire quantity. of digestible protein ingested over and above maintenance requirements appearing in the milk. He holds that these results indicate that a cow can be made to be economical in her usage of nitrogen, if it seems expedient to stint her. *Fühling's Landw. Ztg. 56, 17, pp. 589-593 (1907); Milch Ztg., 36, 40, pp. 469-470 (1907); Abstr. E. S. R. 19, pp. 469-470 (1907).*

Lindsey (1898) reports, without citing details, the results of a trial with 12 cows fed 13 weeks in which rations carrying 1.5, 2. and 2.5 pounds of digestible protein were fed, the digestible nutrients in each ration being essentially identical in amount. About 5 percent more milk was made on the 2-pound protein ration and 10 percent more on the 2.5-pound protein ration than on the 1.5-pound one. The quality of the milk remained unchanged. The author considers that a daily 2 to 2.5 pounds digestible protein intake tends to develop milk-producing capabilities. *Mass. (Hatch) Sta. Rpt. 11, pp. 42-43 (1898); Abstr. E. S. R. 11, p. 577 (1899).*

Lindsey (1900) fed several rations carrying different amounts and kinds of concentrates other than bran and corn or oatmeal which were fed with hay throughout the trials (new process linseed meal, flaxseed meal, gluten meal, cottonseed meal, etc.). He declared that "different amounts of protein do not seem to have any influence on the composition of milk." No data whatever are given as to the effect on the quantity of the milk flow. *Mass. (Hatch) Sta. Rpt. 13, pp. 14-33 (1900); Abstr. E. S. R. 13, p. 385 (1901).*

Lindsey (1910) made eight trials, in six of which the narrower ration made more milk and milk solids, in one slightly less, and in one by the group method, 7 percent less than the wider ration. In this latter case, shrinkages were essentially identical.

He makes interesting comparisons of protein intake and outflow. Assuming 0.7 pound digestible protein as the maintenance need, he deduces the following figures:

| Nutritive ratios | Digestible protein intake | Digestible protein intake ± of milk and maintenance needs | Nutritive ratios | Digestible protein intake | Digestible protein intake ± of milk and maintenance needs |
|---|---|---|---|---|---|
| 1: | lbs. | % | 1: | lbs. | % |
| 3.9 | 3.1 | + 97.5 | 6.8 | 2. | +39. |
| 4. | 2.9 | + 92.8 | 7.2 | 1.8 | +31.3 |
| 4.1 | 3.2 | +122. | 8.9 | 1.7 | +21.4 |
| 5.4 | 2.4 | + 65.3 | 8.9 | 1.5 | + 5.1 |
| 5.8 | 2.4 | + 65. | 9.4 | 1.5 | + 2.3 |
| 6.7 | 2.1 | + 48.6 | 9.6 | 1.4 | + 3.4 |
| 6.7 | 1.9 | + 38.4 | 10.5 | 1.2 | — 0.7 |
| 6.7 | 1.8 | + 28. | 10.6 | 1.3 | — 0.6 |

His summations are interesting, among them being:

1. That a 30 percent digestible protein intake in excess of protein minimum (*i. e.*, 1.8 pounds daily,) should serve the need of a 900-pound cow making 25 pounds of milk; while 50 percent excess (*i. e.*, 2.2 pounds daily) should serve all ordinary requirements.

2. That larger amounts temporarily may increase milk yields but that bovine individuality is as likely as digestible protein to control in this respect.

3. That, ordinarily, variations in the digestible protein intake exert little or no effect on milk composition. *Mass. Sta. Rpt. 23, pp. 86-121 (1910); Abstr. E. S. R. 26, pp. 79-80 (1912).*

Anderson (1899) fed 9 cows for 22 weeks in each of two winter feeding seasons, in groups of three each continuously on a very narrow, a rather high, medium and a wide ration, carrying respectively of digestible protein, digestible carbohydrates and fat (x 2¼) and nutritive ratios: 2.9-3.1, 2.3-2.4, 1.6-1.6; 13.2-13.3, 13.6-13.7, 14.4-14.5; 1:4.3-1:4.5, 1:5.7-1.6., 1:9-1:9.3.

Timothy and clover hays, silage, linseed meal, cottonseed meal, oat chop, gluten feed, corn meal and bran were fed. Live weights were not affected by one ration materially more than by another. The plan of the trial and the published data do not seem to the writer (J. L. H.) to permit one to make safe deductions as to the effect of food changes upon the quantity or quality of the milk flow. *N. Y. (Cornell) Sta. Bul. 173, pp. 59-79 (1899); Abstr. E. S. R. 11, pp. 1081-1083 (1901).*

Hayward (1902) fed 10 cows during three successive winter feeding seasons of about 200 days each. Six cows were used each year, two during two years, 8 for single years. Various rations were fed, ranging in nutritive ratios from 1:3.4 to 1:5.8; 1:4 to 1:7.8; 1:6.2 to 1:11.3 in the three seasons.

Hay was fed as the sole roughage, linseed and corn meals were fed constantly, cottonseed meal during two years and bran and buckwheat middlings during one season. The ingredients never changed during a given feeding season but the proportions were altered from time to time, thus bringing about alteration in the nutritive ratios.

The cows were divided into two groups, one of which was kept on as nearly as might be a uniform ration, the other on rations changing every 40 days. The feeding of the initial and final 40-day periods with each group were identical, but the trial group during the second and fourth periods each year was fed wider, and during the third period much wider, rations than were supplied in the initial or the final periods or than the control group was fed at any time.

During the first trial the daily digestible protein consumption averaged 2.8 pounds and the total digestible nutrient consumption ranged from 16.8 to 19.5 pounds; during the second the figures were 2.4 and 17 to 18; during the third, 1.64 and 14.4 to 17.6. The milk yields ranged and averaged as follows: 22.5 to 15.1, 18.2; 21.5 to 13.1, 17.3; 20.7 to 10.9, 15.2; fat yields 1.09 to 0.76, 0.89; 1.03 to 0.64, 0.81; 0.97 to 0.52, 0.72. The amounts of protein required per pound of milk and per pound of fat were 0.15, 0.14, 0.11; 3.18, 3.02, 2.34. The author states that conclusions "can be" drawn from the data to the effect that "the nutritive ratio between the limits of 1:3.4 to 1:11.3 had no effect upon the quantity or quality of milk production; that 1.3 pounds of computed digestible protein was sufficient for a 1,000-pound cow in full milk, the other conditions necessary to her welfare being met; that, within certain limits, the quantity, digestibility and palatability of the food and its effect upon the animal's general system was of more importance than the relative amount of digestible protein and carbohydrates the ration contained." He also stresses the need of taking account of bovine individuality. *Pa. Sta. Rpt. 1902, pp. 321-396; Abstr. E. S. R. 15, pp. 181-182 (1903).*

Wheeler (1901) discusses the immediate effects on milk production of ration changes, using the data supplied by a study of the record of 981 cows diversely fed during limited periods and during many years, the effect, as a rule, being those exerted within the two to four weeks preceding and following ration changes.

So far as protein is concerned, his conclusions are that, in general, changes within ordinary limits in the amount of protein fed produced less effect than did changes in the amount of total nutrients furnished; that milk flow diminution due to shrinkage was less when the protein intake increased than when it decreased. When both protein and total nutrients intakes increased, the milk flow was maintained; when both decreased, it dropped. When the protein intake was either increased or decreased, while that of total nutrients remained stationary or when protein intake decreased while that of total nutrients increased, normal shrinkage occurred; and when the protein intake increased and that of total nutrients decreased, the shrinkage was marked. In short, the effect upon the milk flow of changes in the total nutrients intakes was much more marked than that of changes in digestible protein intakes. These data indicate that if sufficient available energy is supplied, wide ranges in nutritive ratios may be employed without materially affecting the milk flow. *N. Y. (State) Sta., Bul. 210 (1901); Abstr. E. S. R. 14, pp. 77-78 (1902).*

Morgen, Berger, Fingerling et al. (1904) report concerning studies carried on for six years with sheep and goats, designed to indicate the influence of food fat and protein on milk yields. Rations extremely deficient in fat and rations excessively rich in fat were fed, and fat was substituted for more or less of the protein in highly nitrogenous rations. The addition of fat to a low fat-low protein ration (which, however, contained sufficient digestible nutrients to maintain life and cause gain in body weight) decidedly increased milk yields, including solids, and raised the fat percentages. The addition of protein still more decidedly augmented yields but lowered the solid and fat percentages. The simultaneous addition of both fat and protein increased yields and tended to counterbalance the quality-depressing effect of high protein feeding. The substitution for carbohydrates of fat in equivalent energy values in a high protein-low fat ration increased yields and raised fat percentages. The substitution of fat for protein in equivalent energy values in the same ration increased fat yields and fat percentages in the milk but tended to reduce milk yields.* The addition of carbohydrates to a fat-low protein ration was without effect upon the milk yield. Food fat seemed better suited to the production of milk fat than either protein or carbohydrates and to exert a specific influence on fat yields and composition, an influence not shown when protein or carbohydrates became dominants in the rations. Rations of equivalent energy values were found to exert the same influence on milk yields only when the protein and fat contents were sufficient to induce approximately maximum production.

One of the authors (F.) substituted rice meal, rich in fat, for barley feed, poor in fat, and increased both the absolute yield of fat and the fat percentages in goats' milk. *Landw. Vers. Stat., 61, 1-4, pp. 1-284 (1904); 62, 4-5, pp. 251-386 (1905); 64, 2-3, pp. 93-242; 4-5, pp. 299-412 (1906); 66, 1-2, pp. 63-165 (1907); Abstr. E. S. R. 16, pp. 696-698 (1905); 17, pp. 286-287 (1905); 18, p. 171 (1906); p. 1159 (1907).*

Goldschmidt, Kjeldsen and Lemming (1904) fed for about six months some 75 to 100 cows on seven farms, supplying them with rations adapted in the authors' judgment to their body weights and productive powers. A maintenance ration of 0.7 pound digestible protein and 7 pounds digestible carbohydrates and fat (x 2¼) per 1,000 pounds live weight was supplied and 0.5 pound and 1.3 pounds respectively were added for each 10-pound milk yield, varying, however, in accordance with the exigencies of the trials between 0.4 and 0.6, 1.1 and 1.5 pounds. The authors state that when protein or carbohydrate intakes were increased the natural shrinkage was somewhat checked, especially if this increment was supplied to cows in the early stages of lactation; that when the protein or carbohydrate intakes were decreased the milk flows were lowered. These lessened yields were secured, however, at a smaller price per unit when the protein supply was diminished, since in the main this represented purchased grain. They hold that such a reduction is better justified than is lowered carbohydrate consumption, since carbohydrates generally should be farm produced. A shortened protein supply is deemed particularly inadvisable at the outset of the lactation period or long before the pasture season begins. *Copenhagen (1904), pp. 1-147; Abstr. E. S. R. 16, pp. 908-909 (1905).*

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*The statement on this point in the E. S. R. abstract is obscure and seems capable of a dual interpretation. J. L. H.

Wing and Foord (1904) report an interesting trial involving the feeding of a small herd of cows during four years, the first and fourth under conditions of poor feeding, the second of liberal, the third of liberal feeding yet with due regard to economy. During the first year the ration fed in the barn furnished about 1.3 pounds of digestible protein and its nutritive ratio was about 1:8; and the conditions during the fourth year were similar. During the second year a very liberal and highly proteinous régime was adopted, nutritive ratios ranging from 1:5.5 downwards. During the third year the total food consumption was less but nutritive ratios were about the same. The milk yields during the second and third years averaged about 50 percent larger than during the first and fourth years; and the fat content of the milk was increased by 0.25 percent. *N. Y. (Cornell) Sta., Bul. 222 (1904); Abstr. E. S. R. 16, pp. 695-696 (1905).*

Armsby and Risser (1905) fed to 12 cows for 12 weeks by the combined group-reversal system, rations consisting of mixed hay, silage, corn meal and either distillers' dried grains or cottonseed meal. The rations averaged to carry: 16.7 and 14.7 pounds digestible dry matter, 2 and 2.3 pounds of digestible protein, 14.7 and 12.4 pounds digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:7.5 and 1:5.4. They secured a slight increase in milk yield and a considerable increase in the fat content of the milk as a result of using the wider (distillers' dried grains) ration. *Pa. Sta. Bul. 73 (1905); Abstr. E. S. R. 17, p. 586 (1906).*

One of us (C. E. B.) (1905) while at the Connecticut (Storrs) Station, discussing the data set forth in several of its publications,* cites the results secured in 21 Connecticut farmers' herds, comprising 277 cows, to which were fed rations deemed by station officers to be better adapted to milk production than were those which they replaced. The revised rations averaged to carry ⅔ pound more grain, 1½ pounds less dry roughage and 3 pounds less succulent roughage, ½ pound more digestible protein and 1,070 less calories than did their predecessors. The average daily gain in milk yield was 1.1 pounds. More milk, better manure and cheaper rations resulted, the latter because of the lessened amount of nutrients fed. The augmented flow is attributed to the increase in the amount of grain fed and especially the proportion of grain fed to that of roughage as well as to the additional protein intake. The effect of protein intake increment was most marked when less than 1.5 pounds had been fed in the original ration.

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*Conn. (Storrs) Sta. Rpts. 6, pp. 69-115 (1893); 7, pp. 26-56 (1894); 8, pp. 41-76 (1895); 9, pp. 53-84 (1896); 10, pp. 17-66 (1897); 13, pp. 130-157 (1900); 14, pp. 81-104 (1901).

The writer of the bulletin under review (C. E. B.), as well as the writers of the long series of articles which he discusses, hold that under the economic conditions obtaining when the studies were in process (1893-1901), more protein could have been used to advantage than was commonly fed, particularly in view of increased manurial values.

Still further, in specifically studying the effect of change in the digestible protein intake, he separated the records into three groups, wherein the increment in protein consumption in the modified as compared with the original ration averaged 0.7 pound—being a 50 percent increase; 0.7 pound being a 33 percent increase; and 0.2 pound being an 8 percent increase. The results were as follows:

| | Number of cows | Dry roughage | Succulent roughage | Grain | Digestible protein | Calories | Milk | Fat | Fat |
|---|---|---|---|---|---|---|---|---|---|
| | | lbs. | lbs. | lbs. | lbs. | | lbs. | % | lbs. |
| Orig. 1.4 lbs. prot... | 87 | 14.4 | 9.4 | 7.2 | 1.4 | 25,050 | 15.9 | 4.42 | 0.70 |
| Mod. 2.1 lbs. prot... | 87 | 14.1 | 0.9 | 8.6 | 2.1 | 25,460 | 16.7 | 4.73 | 0.79 |
| Mod. ± orig....... | | — 0.3 | —8.1 | +1.4 | +0.7 | + 410 | + 0.8 | +0.31 | + 0.09 |
| Mod. ± orig. % ... | | — 2 | —90 | +19 | +50 | + 2 | + 5 | +7 | +13 |
| Orig. 2. lbs. prot.... | 96 | 13.2 | 13.5 | 8.9 | 2.0 | 29,100 | 19 | 4.80 | 0.91 |
| Mod. 2.7 lbs. prot... | 96 | 11.6 | 11.9 | 9.8 | 2.7 | 28,350 | 18.8 | 5.08 | 0.96 |
| Mod. ± orig....... | | — 1.6 | — 1.6 | +0.9 | +0.7 | — 750 | — 0.2 | +0.28 | +0.05 |
| Mod. ± orig. %... | | —12 | —12 | +10 | +33 | — 4 | — 1 | +6 | +6 |
| Orig. 2.1 lbs. prot.. | 94 | 16.6 | 5.7 | 9.3 | 2.1 | 30,570 | 16.9 | 4.94 | 0.83 |
| Mod 2.3 lbs. prot.. | 94 | 14.1 | 6.3 | 9 | 2.3 | 27,700 | 17 | 5.06 | 0.85 |
| Mod. ± orig...... | | 2.5 | +0.6 | —0.3 | +0.2 | — 2,870 | + 0.1 | +0.12 | +0.02 |
| Mod. ± orig. %... | | —15 | +10 | —3 | +7 | — 9 | 0 | +2 | +2 |

The writer of the bulletin under review (C. E. B.) holds in the first instance that a part of the increased milk flow (5 percent more milk, 13 percent more fat) was due to the increased total food intake (2 percent) and to the ⅕ increase in grain consumption, particularly in view of the negative results in the two lower sections of the table, in one of which a largely increase protein consumption and a considerably greater grain usage was not reflected in the milk yield. *Conn. (Storrs) Sta., Bul. 34 (1905); Abstr. E. S. R. 16, pp. 911-912 (1905).*

Hindhere (1905), discussing the Copenhagen (Denmark) station feeeding data, holds that protein possesses no special value in increasing the milk secretion, unless the amount previously supplied has been very low. He states that an excess above the physiological protein minimum is desirable only for its potential fuel and manurial values and that it is not advantageous to feed much more than that minimum. He further argues that an economical minimum below the physiological minimum may exist under some circumstances and that no deleterious effect on future production is likely to become apparent if less than the physiological minimum is supplied for a considerable period of time. *Ber. K. Vet. Landbohöj. Lab. Landökon. Forsög 55, pp. 74-104 (1905); Abstr. E. S. R. 16, p. 912 (1905).*

Mairs (1905) reports concerning the results secured with 32 cows during two years. No data are supplied as to the intake, either in terms of pounds of roughage fed, total digestible dry matter or any of the digestible nutrients. Apparently, however, the cows were fed divers amounts of protein. The author states the cows fed the larger amounts of protein made more milk than those fed the smaller amounts; that the composition of the milk was not affected; that the chief advantage derived from the more liberal protein consumption was to be found in the stimulation of bovine appetite which, in turn, induced yet greater consumption and increased production. However, he states that the results seem to indicate that beyond certain limits the supply of protein is of much less importance than was formerly considered to be the case and that an excess of protein beyond that required for maintenance and to furnish the protein of the milk does not materially stimulate production. *Pa. Sta. Rpts., pp. 96-104 (1905); pp. 129-138 (1906); Abstr. E. S. R. 18, p. 472 (1906); 19, p. 876 (1907).*

Thienemann (1905) fed two cows for 75 days, using several rations with nutritive ratios of 1:6:5, 1:7.3, 1:8.1 and 1:8.2. The lowering of the protein and the concomitant increase in the carbohydrate intake produced a lessened milk flow, and somewhat lessened solid and fat percentages. *Fühling's Landw. Ztg. 54, 1, pp. 13-22; 2, pp. 51-55 (1905); Abstr. E. S. R. 16, p. 1011 (1905).*

Certain Danish investigators [names not given in abstract] (1906), used nine fresh cows in studying minimum protein requirements and found that cows giving from 22 to 35 pounds of milk daily used from 1.7 to 2.06 pounds of digestible protein in the rations of mangels, hay, straw and cottonseed meal which were fed. They state that minima necessarily vary with different cows, different rations, different milk flows, etc. *Ber. K. Vet. og. Landb. Lab. Landök. Fersög (Copenhagen) 60, pp. 1-147, 1-158 (1906); Abstr. E. S. R. 18, pp. 668-669 (1907).*

Hansen (1907) reports trials carried out with 51 cows during two years, in which 3.1 pounds total protein or 2.5 to 2.7 pounds of "proteid" with a starch value of 14.4 pounds were found to be needed in order to secure a satisfactory milk flow and gain in weight with a 1,000-pound cow. He states, furthermore, that increasing the protein supply tended to raise the milk yield and to lower the body gain; and that the proportions fed must be varied to suit individual cows. *Arb. Deut. Landw. Gesell, 134 (1907); Abstr. E. S. R. 19, p. 976 (1908); ibid, 171 (1910); Abstr. E. S. R. 25, p. 778 (1911).*

Mallèvre (1907) holds, tentatively, that the studies made and reported upon by many observers as to the relation of non-protein and true proteid food nitrogen to bovine metabolism, and especially to milk production, warrant the conclusion that the total nitrogenous intake and outgo data of cows fed for many months on rations containing either normal or small nitrogen contents, tend to show that the protein requirement for milk production is lower than was held to be necessary prior to 1907, and that non-proteins play an important rôle in animal nutrition. *Soc. Aliment. Rationn Bétail, Compte Rendu., 11, Cong., pp. 29-46 (1907); Abstr. E. S. R. 19, p. 877 (1907).*

Schmeck (1907) fed to two cows several rations containing 2.25, 1.58, 1.21, 0.83 and 0.50 pounds of digestible protein per 1,000 pounds body weight, the nutritive ratios of the rations being respectively 1:6, 1:9, 1:12, 1:18 and 1:30. When fed the two very low protein rations the cows lost weight rapidly. The 1:6 ration proved most effective as a milk producer. *Illus. Landw. Ztg., 27, 41, pp. 373-375 (1907); Abstr. E. S. R. 18, p. 1159 (1907).*

Derwa (1908) holds, as a result of feeding trials with 8 cows, that a ration should contain one gram digestible protein per kilo body weight plus 50 grams per liter of milk produced. This would mean that a 1,000-pound cow giving 30 pounds of milk would get one pound of digestible protein on account of her weight and 1.45 pounds on account of the milk flow. *Rev. Gén. Agron., N. S., 3, 11, pp. 455-458 (1908); Abstr. E. S. R. 20, p. 1175 (1909).*

Savage (1909) fed during two different years 20 and 16 cows by the group-reversal system in 6-week periods, rations in which roots were substituted for concentrates. The rations consisted of: (a) hay, silage, cottonseed meal, corn meal, distillers' dried grains and bran; (b) hay, mangels, cottonseed meal, corn meal and distillers' dried grains; (c) hay, silage, mangels, cottonseed meal, corn meal and distillers' dried grains: during first year; (d) hay, silage, linseed meal, bran, corn meal, buckwheat middlings and distillers' dried grains; (e) hay, mangels, linseed meal, bran, corn meal, buckwheat middlings and distillers' dried grains; (f) hay, silage, mangels, linseed meal, bran, corn meal, buckwheat middlings and distillers' dried grains: during the second year.

No analyses of fodders and feeds seem to have been made except for dry matter in silage and mangels. Using the average data supplied by standard compilations the digestible nutrients supplied in the several rations are as follows, in the order as stated above:

| | Total digestible nutrients | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Nutritive ratios |
|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: |
| (a) ......... | 23.2 | 15.3 | 2.51 | 14.1 | 5.6 |
| (b) ......... | 22.2 | 15.3 | 2.79 | 13.8 | 5 |
| (c) ......... | 23. | 15.2 | 2.18 | 14. | 6.4 |
| (d) ......... | 23.1 | 15.1 | 2.56 | 13.8 | 5.4 |
| (e) ......... | 22.2 | 15.2 | 2.84 | 13.5 | 4.7 |
| (f) ......... | 22.7 | 14.8 | 2.08 | 13.6 | 6.4 |

In rations (d) and (e) mangels replaced silage; in rations (c) and (f) they replaced half the grain. The usages of digestible dry matter were closely similar. The substitution of silage by roots increased digestible protein usage, of grain by roots decreased it.

The plan of the trials was such that the ordinary methods of comparison are not readily applied. However, apparently when mangels replaced one-half the grain ration, 2 percent less and 3 percent more milk, 5 percent less and 1 percent more fat were made, fat percentages being slightly lowered in each instance; when mangels replaced silage, 8 and 10 percents more milk, 1 and 6 percents more fat were made, fat percentages being lowered in each instance; and when silage replaced mangels and, coincidently, roots replaced one-half the grain ration, 2 and 6 percents less milk, 7 and 6 percents less fat were made, fat percentages being lowered in one and unaffected in the other instance. Body weights were taken but the author does not deem it advisable to hazard their interpretation. He deems a pound of dry matter in mangels the equivalent of a pound in silage or "grain" (50 percent distillers' dried grains, 30 percent corn meal and 20 percent cottonseed meal; or 50 percent distillers' dried grains, 20 percent buckwheat middlings, 10 percent each corn and linseed meals and bran). *N. Y. (Cornell) Sta. Bul. 268 (1909); Abstr. E. S. R. 22, p. 76 (1910).*

Savage (1912) presents a historical résumé of feeding standards from the days of Albrecht Thaer to 1912, with special reference to Haecker's work and Armsby's "production values." He set forth the results of trials which he instituted with a view of testing the validity of these dicta. He fed 12 cows in each of two winter seasons (23 cows in all), using both the group and the reversal systems.

The cows were fed mixed hay, silage, mangels, distillers' dried grains, hominy chop, linseed meal and bran the first winter; and clover hay, silage, mangels, distillers' dried grains, hominy chop, gluten feed and bran the second winter. All cows ate the same materials but the proportions of the concentrates in the two grain mixtures varied. The average live weights for each group were very close to 1,000 pounds per cow the first winter and 1,100 pounds during the second winter. The cows had plenty to eat and to spare, from 27 to 32 pounds of total dry matter, from 19 to 23 of digestible dry matter, from 2.2 to 3.1 pounds digestible protein, from 16 to 21 pounds of digestible carbohydrates and fat (x 2¼). Nutritive ratios in 15 of the 18 periods ranged from 1:7 to 1:7.6 and in three periods of from 1:6 to 1:6.3. They ate on the average during the first year 11 percent more total nutrients and 12 percent more "therms" of energy and in the second 7 percent more and 1 percent less than the Haecker or Armsby standards demanded. On the whole the rations fed conformed with reasonable closeness to Haecker's suggestions in so far as nutritive ratios are concerned, although 9 percent more food was eaten.

The author states that he believes "a nutritive ratio of 1:6 will stimulate a greater production of fat than will wider nutritive ratios as proposed by Haecker's standard"—which as a rule lie between 1:7 and 1:8, the lower figures for the thinner, the higher figures for the richer milks; and that "an increase of at least 10 percent in the amount of total nutrients above that allowed by Haecker would stimulate fat production to an extent great enough to pay for the increased feed" (written in 1912). As to Armsby's standard, he holds that while probably more closely representative of relative values of various feeding stuffs than are other proposed standards, they fail in that they do not furnish definite recommendations for varying the supply of nutrients in accordance with different qualities of milk. (Written in 1912.)

Savage then suggests a modification of Haecker's standard, furnishing 35 percent more digestible protein and 10 percent more total nutrients. *N. Y. (Cornell) Sta. Bul. 323 (1912); Abstr. E. S. R. 28, pp. 877-878 (1913).*

Fraser and Hayden (1912) fed 18 cows for 19 weeks, in two groups, one on a ration of clover hay, silage, gluten feed and corn meal, and the other on mixed timothy and clover hay (5:3), silage and corn meal. The data as to nutrient usage are not given directly. Calculated from derived data they are, approximately, for digestible dry matter, digestible protein, digestible carbohydrates and fat (x 2¼) and nutritive ratios: 18.2, 2.4, 15.8 and 1:6; 16.2, 1.4, 14.8 and 1:11. Milk and fat yields and fat percentages were 33.4 and 22.8; 1.07 and 0.76 pounds; 3.20 and 3.34 percents. The former lot made nearly 50 percent more milk and 40 percent more fat than the latter and ate only three-fourths to four-fifths as much digestible food in making a unit of milk or fat. The authors hold that the lack of digestible protein in the wider ration inhibited economical usage of the other nutrients and that excess of carbohydrates will not make good a protein deficiency.

Now apparently the cows in the group fed the wider ration ate about 1.4 pounds of digestible protein daily; yet they shrank profoundly in milk flow, indeed, fully 15 percent the first week they were placed on the 1:11 ration, notwithstanding the fact that at the outset they were in good physical condition. No statement whatsoever is made as to live weights except that the timothy hay lot "ran down rapidly in flesh and condition." However, since the average milk flows in the preliminary period were 37.8 and 36.2 pounds and the fat percentages 3.3 and 3.7, it seems fair to assume that the animals were relatively heavy cows, weighing, perhaps, 1,200 pounds. On that assumption, their daily usage of digestible protein during 19 weeks feeding was not much less than that of several of the cows in the Vermont trials now under consideration, during very many times 19 weeks of continuous feeding; and yet the Illinois cows shrank frightfully in yield and flesh, while the Vermont cows subjected to far more drastic conditions did not shrink materially in milk yield nor did they become very gaunt.

These Illinois results are by all odds the most extreme which have met the writer's (J. L. H.) eye in a very thorough survey of the recorded feeding experiences of more than 30 years. *Ill. Sta. Bul. 159 (1912); Abstr. E. S. R. 27, p. 174 (1913).*

Eckles (1913), studying the question of the nutrients required for milk production, and, incidentally, protein requirements, fed 10 registered farrow cows (5 Jersey, 2 Holstein, 2 Ayrshire, 1 Shorthorn) a uniform ration of alfalfa hay, silage, corn meal, bran and linseed meal in the proportion by weights of hay 1, silage 4, grain 1. Eight cows were fed for approximately a year and two for about four months. They made all sorts of milks, carrying from 3.4 to 6.1 percent fat. They ate very different amounts of the several nutrients as was intended should be the case. Their energy intakes varied from 8.6 to 18.7 therms, their available energy intakes from 3 to 12.6 therms, their digestible protein intakes from 1.1 to 2.3 pounds and available digestible protein intakes from 0.6 to 1.8 pounds. They made from 8.7 to 39.9 pounds milk; from 1.3 to 4.6 pounds of total solids, from 0.46 to 1.29 pounds fat, from 0.35 to 1.15 pounds protein, and the variations in total solids, fat and protein percentages were: 11.3 to 15.4, 3.1 to 6.1, 2.9 to 4.4 percents.

The particular point pertinent to the matter now in hand is the relation of the available protein intake to the protein used in the milk. The cows ate from 1.1 to 2.3 pounds digestible protein, used according to the Armsby production value scheme from 0.42 to 0.61 pounds for maintenance and had available for milk making from 0.6 to 1.8 pounds. The milk contained from 0.35 to 1.15 pounds and the ratio range of protein in milk to available protein in food (*i. e.*, digestible protein less that used for maintenance) was 1:1.31 to 1:1.92. Seven of the ten range from 1:1.68 to 1:1.92. The protein fed was in excess of the amounts indicated by the Armsby or Haecker standards, no attempt being made to determine minimum requirements.

More energy was employed in making a rich than a thin milk, 0.245 therms per pound being used when 3.4 percent milk was made and 0.524

when 6.1 percent milk was made. The results seemed to warrant the conclusion that Haecker's standard was insufficient in the case of rich milk in nine cows; that the production of rich milk requires an increase in feed intake in excess of the increase in the energy value of the milk; and that the lessened cost of fat production in rich milk is due in the main to the lessened maintenance requirements of the lighter weight cows per fat unit.

The author expresses the opinion that "the experiences of skillful feeders alone is sufficient evidence that a very high protein content is necessary to the sustained production of rich milk." He suggests on the basis of these trials and other considerations a modification and extension of the Armsby "production value tables" which he considers "the most accurate basis so far formulated" as to the requirements of milk production. This takes the form of a tentative sliding scale standard of protein and energy values for cows producing milks testing from 3 to 6.5 percent fat. *Mo. Sta., Rsch. Bul. 7, pp. 91-140 (1913); Abstr. E. S. R. 30, pp. 773-774 (1914).*

Hart, Humphrey and their associates (1915-1917) have shown that the quality of the protein ingested may affect the milk yield; that the proteins derived from corn and wheat are less efficiently used in milk production than are those derived from milk (casein, skimmilk powder), oil meal, distillers' dried grains, etc. Their studies seem to furnish results which to some extent run counter to those afforded by digestion trials.[1] *Jour. Biol. Chem. 21, 2, pp. 239-253 (1915); 26, 2, pp. 457-471 (1916); Abstr. E. S. R. 33, pp. 275-276 (1915); 36, p. 174 (1917).*

Hart and Humphrey (1917) fed cows with rations consisting of either: (a) corn stover, or (b) clover hay, corn silage and corn meal, or (c) alfalfa hay, corn silage and corn meal; in each instance adding a "supplement" consisting of a proteinous concentrate (gluten feed, linseed meal, distillers' dried grains or cottonseed meal) and starch, the protein consisting from 10 to 12 percent of the dry matter, 37 to 40 percent of which protein was derived from the supplements. The distillers' dried grains proved to be the best supplement. The plane of nitrogen intake (nutritive ratio) and net available energy of the rations were kept closely uniform—the former being about 1:8.3.

At the end of one of these trials in which clover hay was fed, together with linseed meal as a supplement, casein was added to the ration, the nutritive ratio narrowed to 1:5 and the revised ration fed for three weeks. As a result "the peculiar stimulating effect of liberal protein feeding on mammary activity was strikingly shown." Increased milk and total solid yields resulted. The authors state that the "maintenance of milk flow * * * is very probably secured by * * * high protein feeding." *Jour. Biol. Chem. 31, pp. 445-466 (1917); 35, pp. 367-383 (1918); Abstr. E. S. R. 36, p. 671 (1917); 40, pp. 572-573 (1919).*

Hart and Humphrey (1919), studying the nitrogen metabolism of milch cows fed home-grown cereal grains with clover, hay and corn silage, fed to five cows rations furnishing protein intakes varying from 2.1 to 2.6 pounds

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[1] The only concentrate used in the long-time Vermont feeding trials discussed in this bulletin, which in the hands of Hart and his associates showed a protein utilization figure decidedly unlike those afforded by corn and wheat products, was linseed meal. This was used in only one of the Vermont rations and in quantities furnishing only one-fifth of the digestible protein. Granting the validity of their point of view, the effect upon the outcome of the Vermont trials—if error there was—may safely be deemed to be negligible.

**and nutritive ratios of 1:8.8. Four of the five shrank quite rapidly in milk. The authors hold that it is impossible to furnish enough protein from a ration of clover hay, silage, ground corn, oats and (or) barley to enable a high producing cow to maintain her yield; and state that the rapid decline in milk production during lactation is often due to the low production values of the proteins used and the low plane of protein intake.** ***Jour. Biol. Chem. 38, 3, pp. 515-527 (1919); Abstr. E. S. R. 43, p. 270 (1920).***

**Humphrey and Oosterhuis (1915) compared home-grown grains and purchased proteinous concentrates, feeding three lots of eight cows each rations of alfalfa clover and timothy hay, silage and beets, as roughages and either corn and oats; bran, oats, distillers' grains and cottonseed meal; or bran, oats, corn, distillers' grains and oil meal. The purchased rations cost 3 percent more than the home-grown ration and made 9 percent more product. The nutritive ratios were 1:5.4 and 1:7.9. The purchased ration returned a profit and added to farm fertility.** ***Wis Sta. Bul. 250, pp. 46-47 (1915); Abstr. E. S. R. 33, pp. 381-382 (1915).***

**Ellett and Holdaway (1917) fed two lots of two cows each for long periods of time rations carrying either high energy and low protein values or low energy and high protein values. The cows eating the latter ration (nutritive ratio 1:2.8), though leaving one-fourth of their feed, consumed enough energy and 2½ times as much digestible protein as was needed, which excess was digested, the excess nitrogen being voided in the urine. The low protein cows lost in live weight, the high protein cows gained in live weight. The use of the high protein ration is deemed to favor the production of butter fat from substances other than food fat.**

**Drinkard (1917) noted further that the high energy-fed cows consumed all that was fed, but that digestion coefficients were greatly depressed, that of protein to such an extent as to induce protein starvation and loss of flesh, and that of the digestible nutrients as a whole to such an extent as to approximate maintenance and milk needs.**

**All this is tantamount to indicating that excessive digestible protein usage results in excess elimination of urinary nitrogen and that excessive energy results in lowered digestibility of the nutrients.** ***Va. Sta. Tech. Bul. 12 (1917); Rpts. 15-16, pp. 29-45, '17, pp. 32-34; Abstr. E. S. R. 39, pp. 75-76, 381 (1918).***

**Ellett and Holdaway (1920) made two digestion and nitrogen balance studies of cows long and continuously fed, two a high energy and low protein ration and two a high protein and low energy ration. The cows fed the latter ration secreted more fat than they received, thus tending to confirm previous observations to the effect that such rations promote the formation of milk fat from carbohydrates or protein. The authors' experience indicates that when a cow begins lactation with a deficiency of digestible protein in her ration with enough or more of energy, her digestion coefficients fall, her live weight drops, her yield diminishes at first rapidly then more slowly, until, finally, near the end of the period, her digestion coefficients rise again, and she puts on weight, but does not increase in yield.** ***Va. Sta. Rsch. Buls. 12 (1918); 20 (1920); Abstr. E. S. R. 39, p. 75 (1918), 43, pp. 874-875 (1920).***

## 2. ABSTRACTS RELATING TO THE EFFECT OF DIVERSE RATIONS UPON THE QUALITY OF MILK

Friis (1897) reviews eight years' feeding trials conducted at the Copenhagen (Denmark) station from 1888 to 1896, covering 76 different experiments. In so far as they relate to the effect of food on the quality of the milk, he is of the opinion that they prove that "under practical conditions as found in (Denmark) food exerts an entirely insignificant influence on the fat content of the milk." Many rations were fed but all were normal in character. The question of the effect of abnormal food was not considered. *Malkeritid (1897); Norsk Landmansblad 16, 45, pp. 498-501 (1897); Biet 18, pp. 238-247 (1897); Abstr. E. S. R. 10, pp. 86-87 (1898).*

Arenander (1899) generalizes from data secured at Swedish creameries as to the depressing effect of scant feeding on the fat percentage of milk. He states that on pasturage (June to September) average milk tests 3.7 to 4.25 percent, on ample stable feeding (October to December) 3.3 to 3.5 percent, and on scant stable feeding—a meager allowance of marsh or old stock hay—(January-May) 3.2 to 3.3 percent. He holds that a change from a normal to a super-normal ration does not increase the fat content of milk, whereas a change from a normal to a scant ration and back again depresses and then restores the fat percentage. *Nord. Mejeri Tidn. 14, 6, pp. 76-77, 7, p. 91 (1899); Abstr. E. S. R. 11, pp. 184-185 (1899).*

Knierien and Buschmann (1907) report that large quantities of cocoanut cake fed to a herd of 55 cows tended to increase fat percentages and of brewers' grains to reduce them as compared with bran. *Landw. Jahrb. 36, 2, pp. 185-265 (1907); Abstr. E. S. R. 19, p. 75 (1907).*

## 3. ABSTRACTS DEALING WITH TRIALS IN WHICH UNUSUALLY HEAVY FEEDING OCCURRED

Woll and Carlyle (1899) studied the economy of heavy grain feeding during two seasons, using 8 cows each year, feeding them for three months, the combined group and reversal system being employed. Mixed hay and silage, linseed meal, oats, bran and corn were fed, an average of 8 pounds of grain being fed as a normal and 12 pounds as a "heavy" ration.

No analyses seem to have been made the first year but full data were secured during the second, the substance of which may be stated as follows:

| | Total dry matter, lbs. | Digestible protein, lbs. | Digestible carbohydrates and fat (x 2¼), lbs. | Nutritive ration | Milk, lbs. | Fat, percent | Fat, lbs. | Grain ration fed, lbs. |
|---|---|---|---|---|---|---|---|---|
| Lot A, I, III...... | 23.8 | 1.78 | 15.4 | 1:8.6 | 25.5 | 4.24 | 1.08 | 8 lbs. |
| (Heavy) II...... | 26.6 | 2.28 | 17.3 | 1:7.6 | 26.5 | 4.19 | 1.11 | 12 lbs. |
| Lot B, I, III...... | 24.4 | 1.81 | 15.8 | 1:8.7 | 24.3 | 4.28 | 1.04 | 8 lbs. |
| (No change) II.. | 24.4 | 1.83 | 16.1 | 1:8.7 | 24.3 | 4.28 | 1.04 | 8 lbs. |

No more milk or fat were produced when a 12-pound grain ration replaced an 8-pound ration in the first trial and 4 and 3 percents more were made during the second trial. Of course the unit production of digestible nutrients was greatly diminished when the heavy grain feeding was in operation. Live weights were not increased as a result of heavy grain feeding and after effects upon animal well-being were deemed to be unfavorable. The authors feel that heavy grain feeding is advisable, if at all, only in case of cows of marked dairy tendencies which respond to such feeding in terms of milk rather than of body weight. *Wis. Sta. Rpts. 16, pp. 52-67 (1899); 17, pp. 37-61 (1900); Abstr. E. S. R. 12, pp. 81-82 (1900); 13, pp. 80-81 (1901).*

Waters and Hess (1895) fed nine cows for five months with a view of determining the effect of heavy and light feeding on milk production. Mixed hay and corn stover were used for roughages and cottonseed and corn meals as concentrates. In successive 30-day periods, 6, 12, 18, 12 and 6 pounds of grain were placed in the mangers while 6, from 10.4 to 11.5, from 10.9 to 16.5, from 12 to 13.1 and 6.7 pounds were eaten. No cow ate 18 pounds. The gradual increases and reductions account for undereating in the second and overeating in the fourth and fifth periods. The consumption of roughage sunk as that of concentrates increased, the amounts for the several periods being: hay 9.5, 7.6, 6.4, 5.1, 5.6; stover, 13.1, 8.2, 6.1, 5.2, 6.6. The proportions of digestible nutrients supplied in the form of roughage and concentrates were approximately: ⅓, ⅔; ⅗, ⅖; ⅔, ⅓; ⅔, ⅓; ½, ½. Digestion trials were concurrently made with three cows. The average data appear below:

| | Digestible nutrients | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Nutritive ratios | Milk | Fat | Fat | Digestible nutrients per 100 pounds milk | Digestible nutrients per 1 pound fat |
|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | 1: | lbs. | % | lbs. | lbs. | lbs. |
| 6 lbs. grain...... | 14 | 1.5 | 12.5 | 8.2 | 16.9 | 4.60 | 0.75 | 90.7 | 18.7 |
| 12 lbs. grain...... | 16 | 2.1 | 13.9 | 6.5 | 17.3 | 4.85 | 0.81 | 102.7 | 20.2 |
| 18 lbs. grain...... | 17.2 | 2.6 | 14.6 | 5.4 | 17.7 | 4.96 | 0.84 | 106.1 | 20.6 |
| 12 lbs. grain...... | 14.3 | 2.2 | 12.1 | 5.3 | 16.3 | 5.11 | 0.81 | 95.5 | 17.7 |
| 6 lbs. grain...... | 10.6 | 1.5 | 9.1 | 5.9 | 12.9 | 5.55 | 0.69 | 89.5 | 15.5 |

Body weights were not materially affected. Clearly increases in the amount of digestible nutrients eaten and in digestible protein eaten, especially increases in the proportion of concentrates to roughage, tended to augment milk yields, fat yields, and, on the whole, to increase fat percentages. It took, however, less food to make a unit of product on the lighter grain feeding, and, since less of this food was derived from purchased concentrates, production was secured at a lower cost. *Pa. Sta. Rpt. for 1895, pp. 24-55; Abstr. E. S. R. 8, pp. 822-823 (1897).*

Dolgikh (1903), having studied the literature, points out that while the quantity of the milk flow in general is greater when heavy feeding replaces medium or light feeding, cows differ in their ability profitably to handle food, especially fat. He avers that heavy milk yields can be increased by changes in the feeding, but that these depend largely upon the potential nervous energy of the cow and the physical development of her various organs. *Arch. Vet. Nauk. (St. Petersburg) 33, 11, pp. 1118-1159; 12, pp. 1243-1325 (1903); Abstr. E. S. R. 15, p. 810 (1904).*

Holtsmark (1904) studied the production and food consumption data secured with 846 Norwegian herds and concludes that the increase in production grows smaller relatively as the cows are more heavily fed, that is to say, the largest yields per unit of food consumption are not secured by the heartiest eating. *Arch. Math. og. Naturvid, 26, 2 (1904); Abstr. E. S. R. 16, p. 591 (1905).*

Woll, Voorhies and Castle (1920) fed from 14 to 26 cows in groups by the reversal method, three trials in all being made, designed to compare heavy grain feeding, 1 pound per 3 pounds milk, with light grain feeding, 1 pound per 5 pounds milk. In one trial the fat yield was the basis of grain apportionment instead of the milk yield. The cows fed the heavier ration made 4 percent more product, too little, however, to repay the excess cost of the excess grain. *Cal. Sta. Bul. 323 (1920); Abstr. E. S. R. 44, p. 270 (1921).*

### 4. ABSTRACTS RELATING TO THE VERMONT STATION FEEDING TRIALS (1896-1906)

The writer (J. L. H.) (1896-1906) conducted his first feeding trial with dairy cows in 1889 and has been at it now for more than 30 years. The results published prior to 1895 in the third to ninth Vermont reports and in bulletin 48 are of little importance. He was young in the game, and methods were not standardized. He was guilty of many sins both of omission and commission. Consequently, no reference whatsoever is made to this earlier work in this connection. The results secured in multitudinous feeding trials from 1896 to 1905 inclusive have been set forth in the tenth and nineteenth reports. They are not above criticism. In recalculating the condensed data of seven years' work, contained in the eighteenth report, pages 341-376, the writer has been chastened by the occasional discovery of published error, typographical or mathematical, as has also been the case in recalculating for the purposes of this section of this bulletin the data displayed in the seventeenth to nineteenth reports inclusive. However, no major fault has been disclosed in these resurveys and it is felt that the data compare as to accuracy and the deductions as to validity with similar data and deductions published by other American stations, at which feeding trials of a like nature have been conducted. Of course no comparison is suggested with the results secured with the more refined methods which have been employed during later years.

Since 1906 all dairy feeding work at the Vermont Station has dealt with two projects, namely, the digestible protein requirements and the maintenance requirements of dairy cows; the former reported upon in this bulletin, the latter in bulletin 226.

The data published in the tenth and sixteenth reports inclusive were collated, recalculated and discussed as a unit in the eighteenth report under the title "The Influence of Changes in Feeding upon Milk Production." This compilation dealt with nearly 1,300 "records" made by 327 cows fed during seven successive winter seasons (November-May) by the reversal system. A "record" consisted of the intake of total and digestible dry matter and of the several digestible nutrients and the output in terms of milk, total solids and fat, including live weights, for feeding periods of 18, 23, 27 or 32 days' length, each preceded by non-experimental or preliminary periods of similar feeding of either 10, 12, 15 or 18 days. Data as to cost of production and the relation of the several intakes (total dry matter, digestible dry matter, digestible protein, digestible carbohydrates, calories, etc.) to unit production were also published. These many records were grouped in 29 different ways as set forth in the table on page 345 of the eighteenth report and in detail of the 16 pages following. Many of the generalizations which were hazarded as a result of the study of the tabular matter are pertinent in connection with the long time trials now under survey.

Now in view of the fact that there have been published in the seventeenth to nineteenth reports approximately half as much data again as that included in the summation of the work originally discussed in the tenth to sixteenth issues, it has seemed desirable to recalculate this additional material and to combine it with that of a similar nature heretofore published, thus gathering in condensed form the salient features of all of the 1896-1905 dairy feeding experience at this Station; publishing as a unit the essential outcomes of a quarter of a century's work along dairy feeding lines. The 1896-1905 data thus now combined are based on the use of nearly 500 cows—not separate individuals because the same cow might be used during a half dozen seasons—and nearly 2,000 "records." How many million pieces of original data were involved, no attempt has been made to determine. Costs have not been calculated—they are variable as this generation realizes as never before—nor has any attempt been made to set forth the relation of nutrient intakes to unit production.

Certain of the more pertinent tabular matter, revised, combined and simplified—more particularly those portions having direct bearing upon the matter now in hand, namely, the relation of digestible protein consumption to milk production, appear on the following pages; and some of the generalizations of 1905 are again set forth, modified to some extent as a consequence of the scrutiny of the data supplied by the calculation of the later results.

FOOD CONSUMPTION AND PRODUCTION PER DAY PER 1,000-POUND COW

|  | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|

A. Unchanged rations; unchanged amounts of total and digestible dry matter and of digestible nutrients; nutritive ratio unchanged (384 comparisons):

|  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 24.5 | 15.7 | 2.37 | 13.6 | 5.7 | 18.3 | 14.74 | 5.23 | 2.69 | 0.95 |
| II. ...... | 24.5 | 15.8 | 2.37 | 13.5 | 5.7 | 18.3 | 14.79 | 5.24 | 2.67 | 0.95 |
| II. ± I... | 0 | + 0.1 | 0 | — 0.1 | 0 | 0 | + 0.05 | +0.01 | —0.02 | 0 |
| Percents.. | 0 | + 1 | 0 | — 1 | 0 | 0 | 0 | 0 | —1 | 0 |

B. Changed rations; unchanged amounts of total and digestible dry matter and of digestible nutrients; nutritive ratio unchanged (155 comparisons):

|  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 25.5 | 16.8 | 2.44 | 14.6 | 6.0 | 19.9 | 14.47 | 5.03 | 2.88 | 1.00 |
| II. ...... | 25.6 | 16.9 | 2.48 | 14.5 | 5.8 | 19.9 | 14.47 | 5.07 | 2.88 | 1.01 |
| II. ± I... | — 0.1 | + 0.1 | +0.04 | — 0.1 | —0.2 | 0 | 0 | +0.04 | 0 | +0.01 |
| Percents.. | 0 | + 1 | +2 | — 1 | —3 | 0 | 0 | +1 | 0 | +1 |

C. Changed rations; unchanged amounts of total and digestible dry matter and of digestible nutrients—except digestible protein slightly decreased—nutritive ratio widened (28 comparisons):

|  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 23.6 | 15.3 | 2.36 | 13.2 | 5.6 | 17.0 | 14.58 | 5.18 | 2.48 | 0.88 |
| II. ...... | 23.7 | 15.3 | 2.20 | 13.2 | 6.0 | 16.8 | 14.47 | 5.12 | 2.43 | 0.86 |
| II. ± I... | + 0.1 | 0 | —0.16 | 0 | +0.4 | — 0.2 | — 0.11 | —0.06 | —0.05 | —0.02 |
| Percents.. | 0 | 0 | —7 | 0 | +7 | — 1 | — 1 | —1 | —2 | —2 |

D. Unchanged rations; increased amounts of total and digestible dry matter and of digestible nutrients—except digestible protein; nutritive ratio widened (13 comparisons):

|  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 25.8 | 17.2 | 2.59 | 14.7 | 5.9 | 22.5 | 14.84 | 5.14 | 3.32 | 1.15 |
| II. ...... | 27.3 | 18.1 | 2.54 | 15.6 | 6.3 | 22.5 | 14.80 | 5.15 | 3.32 | 1.15 |
| II. ± I... | + 1.5 | + 0.9 | —0.05 | + 0.9 | +0.4 | 0 | — 0.04 | +0.01 | 0 | 0 |
| Percents.. | + 6 | + 5 | —2 | + 6 | +7 | 0 | 0 | 0 | 0 | 0 |

E. Unchanged rations; slightly decreased amounts of total and digestible dry matter and of digestible nutrients—except digestible protein; nutritive ratio narrowed (41 comparisons):

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 27.0 | 17.9 | 2.65 | 15.5 | 6.0 | 21.8 | 14.64 | 5.13 | 3.14 | 1.09 |
| II. ...... | 26.3 | 17.6 | 2.72 | 15.1 | 5.7 | 21.5 | 14.59 | 5.10 | 3.10 | 1.08 |
| II. ± I... | — 0.7 | — 0.3 | +0.07 | — 0.4 | —0.3 | — 0.3 | — 0.05 | —0.03 | —0.04 | —0.01 |
| Percents.. | — 3 | — 2 | +3 | — 3 | —5 | — 1 | 0 | —1 | —1 | —1 |

F. Changed rations; decreased amounts of total and digestible dry matter and of digestible nutrients—except digestible protein; nutritive ratio narrowed (13 comparisons):

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 27.7 | 18.7 | 2.29 | 16.5 | 7.3 | 17.5 | 14.66 | 5.23 | 2.54 | 0.89 |
| II. ...... | 25.7 | 17.0 | 2.31 | 14.8 | 6.6 | 17.6 | 14.63 | 5.23 | 2.55 | 0.90 |
| II. ± I... | — 2.0 | — 1.7 | +0.02 | — 1.7 | —0.7 | + 0.1 | — 0.03 | 0 | +0.01 | +0.01 |
| Percents.. | — 7 | — 9 | +1 | —10 | —9 | 0 | 0 | 0 | 0 | +1 |

G. Changed rations; unchanged amounts of total and digestible dry matter; amounts of digestible carbohydrates slightly decreased; amounts of digestible protein increased; nutritive ratio narrowed (20 comparisons):

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 26.3 | 17.7 | 2.15 | 15.8 | 7.8 | 20.7 | 14.78 | 5.29 | 3.03 | 1.08 |
| II. ...... | 26.2 | 17.8 | 2.64 | 15.5 | 6.1 | 21.7 | 14.65 | 5.22 | 3.15 | 1.11 |
| II. ± I... | — 0.1 | + 0.1 | +0.49 | — 0.3 | —1.7 | + 1.0 | — 0.13 | —0.07 | +0.12 | +0.03 |
| Percents.. | 0 | + 1 | +23 | — 2 | —22 | + 5 | — 1 | —1 | +4 | +3 |

H. Unchanged rations; unchanged amounts of total and digestible dry matter and digestible nutrients—except protein decreased; nutritive ratio widened (11 comparisons):

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 27.3 | 18.0 | 2.84 | 15.3 | 5.6 | 21.9 | 14.43 | 4.96 | 3.15 | 1.08 |
| II. ...... | 27.2 | 17.8 | 2.64 | 15.3 | 6.0 | 21.1 | 14.59 | 5.13 | 3.02 | 1.06 |
| II. ± I... | — 0.1 | — 0.2 | —0.20 | 0 | +0.4 | — 0.8 | + 0.16 | +0.17 | —0.13 | —0.02 |
| Percents.. | 0 | — 1 | —7 | 0 | +7 | — 4 | + 1 | +3 | —4 | —2 |

**I.** Changed rations; unchanged amounts of total and digestible dry matter and of digestible nutrients—except protein, decidedly decreased; nutritive ratio widened (43 comparisons):

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 25.0 | 16.0 | 2.58 | 13.7 | 5.3 | 17.8 | 14.94 | 5.40 | 2.66 | 0.96 |
| II. ...... | 24.9 | 15.7 | 1.88 | 13.8 | 7.3 | 17.4 | 15.05 | 5.39 | 2.62 | 0.94 |
| II. ± I... | — 0.1 | — 0.3 | —0.70 | + 0.1 | +2.0 | — 0.4 | + 0.09 | —0.01 | —0.04 | —0.02 |
| Percents.. | 0 | — 2 | —27 | + 1 | +38 | — 2 | + 1 | 0 | —2 | —2 |

**K.** Unchanged rations; increased amounts of total and digestible dry matter and all digestible nutrients; nutritive ratio very slightly narrowed (97 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 27.4 | 18.0 | 2.53 | 15.7 | 6.4 | 24.5 | 14.74 | 5.15 | 3.58 | 1.24 |
| II. ...... | 29.3 | 19.4 | 2.81 | 16.8 | 6.2 | 25.2 | 14.77 | 5.17 | 3.67 | 1.29 |
| II. ± I... | + 1.9 | + 1.4 | +0.28 | + 0.9 | —0.2 | + 0.7 | + 0.03 | +0.02 | +0.09 | +0.05 |
| Percents.. | + 7 | + 7 | +11 | + 6 | —3 | + 3 | 0 | 0 | +3 | +4 |

**L.** Changed rations; increased amounts of total and digestible dry matter and all digestible nutrients; nutritive ratio narrowed (392 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 25.6 | 16.6 | 2.25 | 14.5 | 6.8 | 20.6 | 14.37 | 5.05 | 2.96 | 1.04 |
| II. ...... | 27.6 | 18.5 | 2.80 | 15.9 | 5.9 | 21.6 | 14.40 | 5.05 | 3.11 | 1.09 |
| II. ± I... | + 2.0 | + 1.9 | +0.55 | + 1.4 | —0.9 | + 1.0 | + 0.03 | 0 | +0.15 | +0.05 |
| Percents.. | + 8 | +12 | +25 | +10 | —13 | + 5 | 0 | 0 | +5 | +5 |

**M.** Unchanged rations; decreased amounts of total and digestible dry matter and all digestible nutrients; nutritive ratio unchanged (168 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 28.2 | 18.9 | 2.82 | 16.3 | 5.9 | 19.5 | 15.18 | 5.45 | 2.95 | 1.05 |
| II. ...... | 26.2 | 17.6 | 2.61 | 15.1 | 5.8 | 18.7 | 15.26 | 5.53 | 2.81 | 1.01 |
| II. ± I... | — 2.0 | — 1.3 | —2.1 | — 1.2 | —0.1 | — 0.8 | + 0.08 | +0.08 | —0.14 | —0.04 |
| Percents.. | — 7 | — 7 | —7 | — 7 | —2 | — 4 | + 1 | +1 | —5 | —4 |

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|

N. Changed rations; decreased amounts of total and digestible dry matter and all digestible nutrients; nutritive ratio widened (280 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 27.4 | 18.4 | 2.81 | 15.7 | 5.8 | 20.4 | 14.47 | 5.10 | 2.95 | 1.04 |
| II. ...... | 24.6 | 16.2 | 2.11 | 14.2 | 7.1 | 18.6 | 14.57 | 5.16 | 2.71 | 0.96 |
| II. ± I... | — 2.8 | — 2.2 | —0.70 | — 1.5 | +1.3 | — 1.8 | + 0.10 | +0.06 | —0.24 | —0.08 |
| Percents.. | —10 | —12 | —25 | —10 | +22 | — 9 | + 1 | +1 | —8 | —8 |

O. Changed rations; decreased amounts of total and digestible dry matter and all digestible nutrients; nutritive ratio slightly widened (277 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 28.3 | 19.0 | 2.72 | 16.3 | 6.4 | 21.2 | 14.81 | 5.26 | 3.09 | 1.07 |
| II. ...... | 26.3 | 17.6 | 2.44 | 15.2 | 6.7 | 20.4 | 14.85 | 5.33 | 2.94 | 1.04 |
| II. ± I... | — 2.0 | — 1.4 | —0.28 | — 1.1 | +0.3 | — 0.8 | + 0.04 | +0.07 | —0.15 | —0.03 |
| Percents.. | — 7 | — 7 | —10 | — 7 | +5 | — 4 | 0 | +1 | —5 | —3 |

P. Changed rations; increased amounts of total and digestible dry matter and digestible nutrients—except protein, which is decreased; nutritive ratio widened (48 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 25.5 | 16.7 | 2.64 | 14.4 | 5.5 | 20.9 | 14.50 | 5.04 | 3.03 | 1.05 |
| II. ...... | 26.7 | 17.7 | 2.44 | 15.8 | 8.0 | 20.8 | 14.47 | 5.00 | 3.01 | 1.04 |
| II. ± I... | + 1.2 | + 1.0 | —0.20 | + 1.4 | +2.5 | — 0.1 | — 0.03 | —0.04 | —0.02 | —0.01 |
| Percents.. | + 5 | + 6 | —8 | +10 | +45 | 0 | 0 | —1 | —1 | —1 |

Q. Changed rations; decreased amounts of total and digestible dry matter and of digestible nutrients—except digestible protein, which is increased; nutritive ratio narrowed (63 comparisons):

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1: | lbs. | % | % | lbs. | lbs. |
| I. ....... | 27.8 | 19.0 | 2.29 | 16.8 | 7.7 | 19.9 | 15.01 | 5.38 | 2.95 | 1.05 |
| II. ...... | 25.9 | 17.7 | 2.77 | 15.2 | 5.6 | 19.6 | 15.12 | 5.47 | 2.93 | 1.05 |
| II. ± I... | — 1.9 | — 1.3 | +0.48 | — 1.6 | —2.1 | — 0.3 | + 0.11 | +0.09 | —0.02 | 0 |
| Percents.. | — 7 | — 7 | +21 | —10 | —27 | — 2 | + 1 | +2 | —1 | 0 |

1. *As to the quality of milk.* In but a single instance (H, 11 comparisons) was the quality of the milk changed, and then the increase was but 0.17 percent fat; and four-fifths of this change is located in three of the 11 comparisons. This is tantamount to saying that, when collated in the manner shown in the preceding tables, only three out of nearly 2,000 comparisons was there manifested any material change in the quality of the milk as a result of changes in feeding. It should be remembered in this connection that these comparisons have to do with the records made by cows after they had been placed on a definite ration for from 10 to 15 days, giving them some little time in which to become accustomed to the change in feed; that, in other words, the comparisons were made in such fashion that in case temporary changes in quality were brought about as a result of ration changes—which does not necessarily occur—they were largely eliminated. Furthermore, it should be remembered that, owing to the large number of cows used and the great number of comparisons made, the bovine personal equation was practically eliminated. The thesis that under normal conditions food changes do not materially affect the fat content of milk has now become so thoroughly established as to need little further argument; yet such a weight of testimony as is here adduced by the data secured during ten years with nearly 500 cows making nearly 2,000 "records" is rarely supplied; and hence the emphasis laid upon it.

2. *As to experimental error.* Table A, covering 384 comparisons, furnishes ample testimony, if such is needed, that the factor of experimental error is not one which need be reckoned with provided the number of observations or comparisons is reasonably large. In this connection, attention is invited to ten years of work along this line, cited in the eighteenth report, page 403.

3. *Relation of food consumption and milk production.*

a. When like quantities of the several nutrients were eaten, production remained unaltered (A, B, E).

b. A 5 percent change in total and digestible dry matter consumption entailed no change in production; a 7 to 8 percent change was followed by a 3 percent change in production; and a 10 to 12 percent change by an 8 percent change in production. In other words, as food intake varied, so did the yields of milk and solids, but to a less degree. In those comparisons wherein larger proportions of digestible dry matter were derived from the grain rations on one side of the comparisons than there were on the other, there appeared to be a tendency towards a somewhat larger production when rations were used in which the proportion of concentrate to roughage was relatively greater (D, F, K to Q).

c. When like quantities of total and digestible dry matter were eaten, but either less or more digestible protein was supplied, the milk flow was accordingly increased or diminished; that is to say, when the digestible protein supply was inordinately or disproportionately raised or lowered, as compared with that of the other nutrients, the gains or losses in yields were still further modified in the direction of the digestible protein change, to the extent on the average of 2 percent, as compared with similar gains or losses when all the nutrients were proportionately raised or lowered. In other words, the milk yields increased or decreased with more or less food intake, raising a little higher and shrinking a little more in accordance with the relative liberality on the one hand or paucity on the other of the digestible protein intake (C, G, H, I).

d. *Concerning digestible protein.* A 3 percent increase or decrease in digestible protein intake was without effect upon production; a 10 percent increase or decrease was accompanied by a corresponding change in yield, amounting to 2 to 3 percent; and a 20 to 25 percent increase or decrease by a corresponding change, amounting to 4 to 5 percent.

*When the digestible protein content of the ration was lowered* and other nutrients were eaten in like quantities, yields were diminished by 2 to 3 percent (C, H, I); when digestible protein alone among the nutrients was not increased in quantity, yields remained unchanged (D); when digestible protein alone was lowered in quantity and all the other nutrients were increased, the yields dropped 1 percent (P).

When all the nutrients were lessened proportionately in amounts, yields decreased 4 percent (M, O).

When all the nutrients were lessened in amount, the digestible protein proportionately to the greatest extent, the yields dropped 8 percent (N).

*When the digestible protein content of the ration was raised,* and the other nutrients were eaten in like quantities, the yields increased 4 percent (G); when digestible protein alone among the nutrients was not decreased in quantity, yields remained unchanged (E, F); when it alone among the nutrients was increased in quantity and all other nutrients were decreased in quantity, the yields dropped 1 percent (Q).

When all the nutrients were increased proportionately, yields showed a 3 percent gain (K).

When all the nutrients were increased in amounts, digestible protein proportionately to the greatest extent, yields were increased by 5 percent (L).

The writer summed up his judgment, touching food effects upon milk yields, 15 years ago as a result of his study of the data presented in the eighteenth report, in the following words, which he feels accurately represents his present point of view, formed after a resurvey of the entire augmented material as well as of the results obtained during the prolonged study, the results of which are set forth in this bulletin.

"The ultimate effect of a given food supply upon the milk flow is doubtless the more or less composite result of several coincidently active factors, including, primarily, changes in the amounts of digestible nutrients taken as a whole; secondarily, changes in the amounts of digestible protein; and, probably, in the third place, modifications in the proportions of digestible nutrients consumed in concentrates and in roughage.

"The writer's study of these data leads him to the conclusion that as a whole they do not support the doctrine which lays extreme stress on the paramountcy of protein; that they indicate that a ration with a nutritive ratio wider than 1:6, perhaps as wide as 1:7, or, indeed, in some cases one slightly wider, may prove economically as effective as the traditional 1:5.4; that a sufficiency of nutrients, affording enough available energy for bodily needs, if carrying a fair amount of digestible protein, not necessarily as much as 2.5 pounds, may prove economically as serviceable as does a richer ration." *Vt. Sta. Rpts., 17, pp. 462-511 (1904); 18, pp. 341-404 (1905); 19, pp. 302-331 (1906); Abstr. E. S. R. 17, pp. 284-285, 1105-1106 (1905-1906); 19, p. 273 (1907).*

## 5. ABSTRACTS RELATING TO THE MINNESOTA FEEDING TRIALS, 1900-1914

Haecker's principal investigations (1900-1914) dealing with the protein problem were carried on during several winters and have attracted rather more attention than have other studies, more particularly because of the wide currency given to certain observations as to the physical well-being of the cows made by the late Ex-Governor W. D. Hoard of Wisconsin. The data were secured in detached winter feeding trials, no long continued consecutive work having been done. Several of the earlier trials were conducted for short feeding periods only and, consequently, the validity of the results may properly be questioned. The trials conducted during four successive winters, 1901-02 to 1904-05, were comprehensive, the results afforded were quite definite and many suggestive deductions have been drawn.

The following statement seems accurately to set forth the conditions obtaining during the eight successive periods of winter feeding at the Minnesota Station from 1901-02 to 1908-09 (designated a-h inclusive):

(1) The average daily digestible protein intakes were: (a) 2, 1.7, 1.3; (b) 1.9, 1.3; (c) 2, 1.3; (d) 1.9, 1.3 and 1.9 (to same group); (e) 1.6; (f) 1.7; (g) 1.8; (h) 1.9.

(2) The average length of the winter feeding periods, stated in terms of months, were: (a) 2; (b) 3.3; (c) 6.3; (d) 5.7; (e) 5.6; (f) 5.1; (g) 5.4; (h) 5.3.

(3) The group system was used throughout, three groups being used in 1901-02, two from 1902-03 to 1904-05, and single groups only from 1905-06 to 1908-09.

(4) The numbers in the groups were: (a) 6, 6 and 6; (b) 10 and 9; (c) 7 and 7; (d) 9 and 10; (e) 16; (f) 22; (g) 17; (h) 25.

(5) No statement whatsoever is made as to the feeding or the life history of the cows during approximately seven months of each year. If records were kept, they have not as yet been published, so far as the writer is aware. Not the slightest clue is furnished as to their feeding during this time, whether it was liberal or scanty, or as to the protein content of the rations fed during the late springs, summers and autumns of 1901 to 1909 inclusive.

(6) The personnel of the groups varied from year to year. There were 150 registrations, 25 cows being used but once, 7 twice, 5 thrice, 3 four times, 3 five times, 2 six times, 7 seven times and one throughout the entire 8 winters. Fifty-three different cows were used. Sometimes the same animals were used in consecutive winters and sometimes not; sometimes cows fed either as much as 1.9 to 2 pounds or as little as 1.3 pounds of digestible protein one season (during the years 1901-02 to 1904-05) were fed a similar amount during succeeding seasons and sometimes they were fed quite different amounts. In the 18 instances in which with a given cow two or more feeding seasons occurred during the first four years when comparative rations were being fed, in 11 the rations fed during successive winters were of the same general character as regards their digestible protein intakes, while in 7 the rations fed during two or more winters were highly dissimilar in this respect.

(7) The only statements made as to the physical well being of the cows in connection with these studies may be succinctly set forth as follows:

1902-03. 9 cows fed an average of 1.3 pounds of digestible protein, average weight 850 pounds; 10 cows fed an average of 1.9 pounds digestible protein, average weight 880 pounds; for an average of 100 days; 10 having been fed either averages of 2, 1.7 or 1.3 pounds digestible protein during eight weeks in the preceding winter, only one, however, receiving 1.3 for eight weeks in 1901-02 and the same amount for 12 weeks in 1902-03. Judged by the then station director, chemist, veterinarian and animal husbandman: "little difference in the general appearance of the groups; in good physical condition; group I. (fed 1.3 pounds 96 days) (being) a little more spare."

1903-04. 7 cows fed an average of 1.3 pounds digestible protein, average weight 860 pounds; 7 cows fed an average of 2 pounds digestible protein, average weight 910 pounds; for an average of 192 days; 5 of the cows were under test for the third successive winter, 6 for the second and 3 were newcomers. The protein intakes of the first five during the three successive winter feeding periods of 56 days, 84 days and 192 days were 2, 1.3 and 1.3; 2, 1.9 and 2; 1.7, 1.9 and 1.3; 1.3, 1.9 and 2; and 1.3, 1.3 and 1.3 pounds. The protein intakes of the six fed during two successive winter feeding periods of 84 and 192 days were in four instances 1.9 and 2, and of two were 1.3 and 1.3 pounds. The three newcomers ate 2, 1.3 and 1.3 pounds. Judged by the same station officials as in the preceding year: "The cows receiving the low protein ration, though rather spare, were apparently in fine physical condition."

Dean W. A. Henry (then Director of the Wisconsin Experiment Station), judging the animals by pairs, *i. e.*, a 2-pound digestible protein intake cow vs. a 1.3-pound digestible protein intake cow, could detect "no apparent difference in their physical condition"; judging the groups as a whole he deemed both to be "in good working condition," but those fed the lower protein ration to be "a trifle spare."

The late Ex-Governor W. D. Hoard of Wisconsin, judging by pairs, "feeling the coat and skin on various parts of the body * * * paying little attention to the appearance of the cows" in seven comparisons infallibly selected the cow fed the lower protein ration and detected the one case when two cows were paired for his judgment, both of which had been similarly fed. "He had little difficulty in pointing out the ones fed on a low protein ration" and stated that his basis of judgment was "the feel of the skin," *i. e.*, its thickness or thinness, the thin skinned cows being deemed the low protein fed animals. The author concludes on the basis of this examination—which in another portion of the bulletin he characterizes as "remarkable decisions"—that despite the fact that "in general appearance the two groups were closely matched * * * though one (was) a trifle sparer than * * * the other * * * there was a difference in their physical condition."

1904-05. No physical examination was made. However, the author refers to "the impoverished condition of the nitrogenous substances of the body of the cows that had been on the very-low-protein rations for from two to four winters." Of the 10 cows on the low protein ration, one had been thus fed during four winters, an aggregate, so far as there is any record to indicate, of 14.7 months out of 40; three had been thus fed three winters, an aggregate apparently of 14.2 months out of 29.5; two had been thus fed two winters, an aggregate apparently of 10.2 months out of 19; an average of less than one-half the time.

The feeding system employed at the Minneapolis station during the following winters up to and including 1908-09 furnished a more liberal protein supply. In the four trials wherein comparisons between a 1.9- to 2-pounds and a 1.3-to 1.4-pound digestible protein ration were instituted, in three years out of four the group fed the larger amount of digestible protein made the most milk; in each year the most total solids and fat; twice its milk carried a lower and twice a higher total solid percentage; twice a higher, once a lower and once an unchanged fat percentage; and twice a lower body weight was secured when the lower protein ration was fed and once the live weight remained unchanged, while no record was available in one case. In each instance the cows fed the larger amount of digestible protein received the larger amount of digestible nutrients, the increases being 5, 11, 5 and 9 percents, whereas the milk yield increases were 4, 6, —6 and 22 percents.

Speaking broadly, the increased intakes of digestible protein and, simultaneously, of total digestible nutrients resulted in more milk, total solids and fat. *Minnesota Sta. Bul. 140 (1914); Abstr. E. S. R. 31, pp. 670-673 (1914).*

Some stress is laid by the writer (J. L. H.) on this analysis of the published data relating to the Minnesota experiments for the reason that much has been made of the single physical examination conducted by the late Ex-Governor Hoard, the results of which, moreover, were quite counter to those made by another skilled observer at the same time with the same cows. These "remarkable decisions" have been heralded far and wide. They have led one of the best of our feeding authorities to declare in a textbook which has extremely wide vogue, of which many editions have been printed—referring to the Haecker cows—that "under good care and otherwise liberal feeding (the cows) for long periods continue(d) a good flow of milk on a surprisingly small allowance of crude protein, (but that) after some years of such feeding their vitality was so depleted that they became physical wrecks long before their time."

Such statements seem to the writer to be unfortunate; for they are predicated upon a single observation made by one person only upon nine cows, which, so far as published records indicate, had not been fed for "some years" "on a surprisingly small allowance of crude protein" but of one cow thus fed during 11 of 30 months, of three cows thus fed during 9 of 18 months, and of some fed thus for only six and a half months. The wide currency given this statement—which, in the writer's opinion, does not appear to be warranted by the published data—seems particularly unfortunate in view of the fact that it is not in line with the results secured here. The Vermont results, furthermore, were secured with large numbers of cows which were fed, not during a few isolated winter seasons, but for 12¼ years, 365 (or 366) days in the year, year in and year out on low, indeed, on very low protein rations, judged repeatedly during several years, not by single individuals but by several different boards of experts in animal nutrition, veterinarians, investigators and teachers in dairy and animal husbandry, practical breeders, cattle buyers and the like; judged, furthermore, not simply on the basis of "the feel of the skin" but in a dozen or more different ways.

Haecker[1] states that "the animal body can stand shortage of protein for several months, and then show the bad effect only to the trained observer. It was found necessary to continue the cows on low protein diet for three years before it was possible to state the effect with certainty. When the change does come, it comes quickly and the results are marked." This statement is made apart from all data substantiating it. It is based, of course, upon the results reported in bulletin 140, and its predecessors. Particular attention should be paid to the statement made by the writer (J. L. H.) in the preceding paragraph as to the extent of the trials.

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[1] Minn. Sta. Rpt. 21, p. 30 (1913).

The second sentence in the above quoted material is the only indication the writer has been able to find anywhere to the effect that the Minnesota cows were "continue(d) on the low-protein diet for three years." This statement does not occur in any bulletin given over to the description of the trials in question, so far as the writer can ascertain by careful reading, nor, so far as the writer is aware, does any statement remotely resembling it occur in any other publication.

## 6. ABSTRACTS RELATING TO THE MISSOURI SUB- OR SUPER-NORMAL FEEDING TRIALS

Eckles and Palmer (1916) overfed or underfed—or both—6 registered cows, the records of which are applicable to the present study. The writer (J. L. H.) has worked over the original data published by the authors in a somewhat different fashion than they followed, but feels confident that the outcome in each case is accurately portrayed.

Alfalfa hay and grain (4 parts corn meal, 2 parts wheat bran, 1 part linseed meal) were fed to all the cows and silage or green alfalfa to three of them. No analyses other than the determination of energy values seem to have been made, or, at any rate, published in the bulletins reviewed. However, using average analyses and digestion coefficients it would appear that presumably the cows fed no silage ate rations of a very uniform nutritive ratio, 1:4.7 or 4.8, whereas those fed silage or green alfalfa ate rations with nutritive ratios ranging from 1:5.4 to 1:6.1 (with one exception, 1:6.6). In 15 of the comparisons made in the following pages, 1.8 pounds digestible protein or more were eaten per 1,000 pounds of live weight; in five instances from 1.4 to 1.65 pounds and in two, 1. and 1.2 pounds.

The salient features of the trials, according to the method employed in this discussion and from the point of view of this bulletin, are set forth in the following table:

| Cow number and breed | | Days in milk at outset | Days in trial | Alfalfa hay | Grain | Silage or green alfalfa | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Nutritive ratio | Therms | Plane of nutrition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | lbs. | lbs. | lbs. | lbs. | lbs. | 1: | | ± |
| 402 | (1) | 150 | 11 | 13.5 | 9 | ... | 2.42 | 11.53 | 4.8 | 11.5 | + 8 |
| Shorthorn | (2) | | 62 | 23.4 | 15.8 | ... | 4.23 | 20.10 | 4.7 | 20 | +77.7 |
| | (3) | | 34 | 9.6 | 6.5 | ... | 1.74 | 8.25 | 4.7 | 8.3 | —21.1 |
| 2 | (1) | 14 | 6 | 8 | 2.5 | 20 | 1.43 | 8.39 | 5.9 | 8 | — 2 |
| Jersey | (2) | | 84 | 8.3 | 10 | 20 | 2.21 | 13.12 | 6 | 13.8 | +56.5 |
| | (3) | | 4 | 8.5 | 4 | 20 | 1.56 | 9.53 | 6.1 | 9.1 | — 7 |
| | (4) | | 10 | 10 | 11 | 20 | 2.50 | 14.49 | 5.8 | 15.1 | +59.5 |
| | (5) | | 12 | 10 | 3.6 | 20 | 1.66 | 9.95 | 6 | 9.5 | — 1 |
| 62 | (1) | 75 | 7 | 13.6 | 14.4 | * | 3.04 | 16.78 | 5.5 | 18.3 | +75 |
| Jersey | (2) | | 16 | 3.2 | 3.2 | 12.5 | 0.82 | 5.44 | 6.6 | 5.5 | —46.6 |
| | (3) | | 13 | 6 | 6 | 24 | 1.56 | 10.31 | 5.4 | 10.6 | +14.7 |
| 2 | (1) | 3 | 70 | 7.7 | 4.2 | 10.3 | 1.38 | 7.69 | 5.6 | 7.5 | —26.4 |
| Jersey | (2) | | 17 | 10 | 8.6 | 17.1 | 2.20 | 12.54 | 5.7 | 12.9 | +36.1 |
| | (3) | | 7 | 8 | 3.1 | 10 | 1.28 | 7.11 | 5.6 | 6.8 | —30.5 |
| 301 | (2) | 2 | 33 | 8.1 | 5.5 | ... | 1.46 | 7.02 | 4.8 | 6.9 | —36.9 |
| Ayrshire | (2) | | 6 | 12.8 | 7.5 | ... | 2.18 | 10.30 | 4.7 | 10.1 | . 0 |
| 20 | (1) | 1 | 34 | 7.5 | 3.7 | ... | 1.21 | 5.61 | 4.7 | 5.4 | —61.8 |
| Jersey | (2) | | 12 | 14.1 | 7 | ... | 2.25 | 10.56 | 4.7 | 10.3 | —22.3 |
| | (3) | | 16 | 15.3 | 8 | ... | 2.49 | 11.62 | 4.7 | 11.3 | —12 |
| 206 | (1) | 0 | 22 | 9 | 4.5 | ... | 1.44 | 6.77 | 4.7 | 6.5 | —60.5 |
| Holstein | (2) | | 12 | 16.7 | 8.5 | ... | 2.69 | 12.64 | 4.7 | 12.4 | —19.6 |
| | (3) | | 8 | 20 | 10 | ... | 3.20 | 15.03 | 4.7 | 14.5 | — 7.9 |

| Cow number | Live weight | Milk | Total solids | Fat | Total protein | Milk sugar and ash | Total solids | Fat | Total protein | Milk sugar and ash | Plane of nutrition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | % | % | % | % | lbs. | lbs. | lbs. | lbs. | |
| 402 | 1130 | 13.4 | 13.56 | 4.06 | 3.31 | 6.19 | 1.81 | 0.54 | 0.44 | 0.83 | Normal |
| | 1205 | 15.4 | 13.29 | 3.69 | 3.66 | 5.94 | 2.05 | 0.57 | 0.56 | 0.91 | Supernormal |
| | 1155 | 10.8 | 13.17 | 4.00 | 3.44 | 5.73 | 1.42 | 0.43 | 0.37 | 0.62 | Subnormal |
| 2 | 726 | 10 | 13.64 | 4.42 | 3.64 | 5.58 | 1.36 | 0.44 | 0.36 | 0.56 | Normal |
| | 784 | 11.2 | 13.94 | 4.53 | 3.50 | 5.91 | 1.56 | 0.51 | 0.39 | 0.66 | Supernormal |
| | 850 | 10.8 | .... | 5.54 | ... | ... | ... | 0.60 | ... | ... | Normal |
| | 857 | 11.5 | .... | 4.86 | ... | ... | ... | 0.56 | ... | ... | Supernormal |
| | 859 | 11.9 | .... | 4.84 | ... | ... | ... | 0.58 | ... | ... | Normal |
| 62 | 907 | 17.4 | 15.13 | 4.70 | 4.25 | 6.18 | 2.63 | 0.82 | 0.74 | 1.08 | Supernormal |
| | 861 | 13.7 | 14.88 | 5.65 | 3.61 | 5.62 | 2.04 | 0.77 | 0.49 | 0.77 | Subnormal |
| | 864 | 13.9 | 13.64 | 4.44 | 3.65 | 5.55 | 1.89 | 0.62 | 0.51 | 0.77 | Supernormal |
| 2 | 939 | 13 | 14.47 | 4.73 | 3.60 | 6.14 | 1.87 | 0.61 | 0.47 | 0.80 | Subnormal |
| | 896 | 11.6 | 14.04 | 4.58 | 3.49 | 5.97 | 1.62 | 0.53 | 0.40 | 0.69 | Supernormal |
| | 921 | 12 | 14.28 | 4.74 | 3.52 | 6.02 | 1.71 | 0.57 | 0.42 | 0.72 | Subnormal |
| 301 | 887 | 19.3 | 12.23 | 3.60 | 3.14 | 5.49 | 2.36 | 0.69 | 0.61 | 1.06 | Subnormal |
| | 854 | 16.2 | 12.29 | 3.69 | 3.12 | 5.48 | 1.99 | 0.60 | 0.50 | 0.89 | Normal |
| 20 | 754 | 20.7 | 15.77 | 6.00 | 3.91 | 5.86 | 3.26 | 1.24 | 0.81 | 1.21 | Very subnormal |
| | 716 | 25.9 | 13.72 | 4.46 | 3.36 | 5.90 | 3.55 | 1.16 | 0.87 | 1.53 | Subnormal |
| | 723 | 25.7 | 13.51 | 4.21 | 3.47 | 5.83 | 3.47 | 1.08 | 0.89 | 1.50 | Supernormal |
| 206 | 1218 | 30.5 | 11.77 | 3.85 | 2.88 | 5.04 | 3.59 | 1.17 | 0.88 | 1.54 | Very subnormal |
| | 1140 | 29 | 11.66 | 3.66 | 2.62 | 5.38 | 3.38 | 1.06 | 0.76 | 1.56 | Subnormal |
| | 1167 | 31.3 | 11.38 | 3.27 | 2.72 | 5.39 | 3.56 | 1.02 | 0.85 | 1.69 | Normal |

### OVERFEEDING FOLLOWING UNDERFEEDING

No. 402, 5 months in milk, was slightly overfed for 11 days, heavily overfed for the next 62 days, then within 6 days dropped to decided underfeeding, being underfed for 30 days.

No. 402 (2), heavily overfed for two months, gained 7 percent in live weight, 15 percent in milk, 13 percent in solids, 6 percent in fat, 27 percent in protein and 10 percent in sugar and ash. The quality of the milk was altered, total solids, fat and sugar-ash dropping 2, 9 and 4 percents and protein increasing 11 percent coincident with a very large increase in protein intake. Live weights consistently climbed upwards throughout the period and the milk flow was maintained without diminution.

No. 402 (3), decidedly underfed for a month following two months of extreme overfeeding, and receiving but 1.5 pounds of digestible protein per 1,000 pounds live weight, lost 4 percent in live weight, 30 percent in milk, 31 percent in solids, 25 percent in fat, 34 percent in protein and 32 percent in sugar-ash. The quality of the milk was altered, solids dropping 1 percent, protein 6 percent (coincident with the withdrawal of more than 50 percent of the digestible protein in the ration) and sugar-ash 4 percent, while fat increased 8 percent. Live weights dropped consistently, all the previous gains being lost; yet, notwithstanding the apparent usage of these accumulations, the milk yields fell sharply.

### OVERFEEDING FOLLOWED BY NORMAL FEEDING

No. 2, two weeks in milk, fed a normal standard ration for a week, was heavily overfed for three months, normally fed for four days, heavily overfed for 10 days and normally fed for 12 days.

No. 2 (2), heavily overfed for almost three months, gained 8 percent in live weight, 12 percent in milk, 13 percent in solids, 14 percent in fat, 6 percent in protein and 16 percent in sugar-ash. Live weights consistently advanced after the third week and the milk flow held up or indeed slightly advanced as the period grew to an end.

No. 3 (3). When, following three months of heavy feeding, four days of normal feeding ensued, as compared with the results secured at the end of the former period, live weight dropped 2 percent and milk yield 6 percent. The fat percentage ballooned during these four days, the records being: Average of four days immediately preceding this period (super-normal feeding) 4.66; four days of normal feeding, 5.80, 5.40, 5.50, 5.40; two days on renewed super-normal feeding, 5.00, 4.70. Hence, although milk yield dropped 6 percent, fat yield increased 15 percent.

No. 2. (4). When super-normal feeding was again resorted to for ten days, live weights began to increase, the milk flow increased, becoming as large or larger than at any previous period, and its quality became normal.

No. 2 (5). When, finally, normal feeding was resumed and continued for 12 days, live weight was maintained, the milk flow still further increased, and the fat percentage held at a constant figure. Unfortunately, the protein contents of the milk were determined only in the first two periods and the effect of the changes in protein intakes (1.9, 2.8, 1.8, 2.9, 1.9 pounds per 1,000 pounds of live weight) can not be studied. The initial change, however, was without effect.

### UNDERFEEDING FOLLOWING A WEEK'S OVERFEEDING, SLIGHT OVERFEEDING FOLLOWING UNDERFEEDING

No. 62, 2½ months in milk, heavily overfed for a week, underfed for two weeks then slightly overfed for two weeks.

No. 62 (2), fed a half ration for 16 days, following a week of super-normal feeding and an interval of 11 days concerning which little record is furnished, but in which, for part of the time at least, normal feeding occurred—as compared with the 7-day period of super-normal intake, shrank 5 percent in live weight and, in milk, solids, fat, total protein and sugar-ash, 21, 22, 6, 34 and 29 percents, respectively. The quality of the milk was profoundly affected, solids, protein and sugar-ash dropping 2, 15 and 9 percents, while fat increased 20 percent. The sharp drop in protein followed a reduction of 70 percent in protein intake. Live weights, milk yields, protein and sugar-ash percentages fell consistently from the outset. The fat percentage skyrocketed from the second day, falling again toward the end of the period.

No. 62 (3). When, following 16 days of decided underfeeding, the cow was slightly overfed for 13 days, live weight increased a little, being 4 percent higher during the last nine days than in the first four days; the milk yield increased slightly, being 2 percent larger than in the sub-normal feeding period and 9 percent larger than during its last six days. The quality of the flow was again profoundly affected owing to the return of the fat percentage to normality, solids shrinking 7 and fat 20 percents.

### UNDERFEEDING FOLLOWED BY OVERFEEDING AND BY UNDERFEEDING

No. 2, fresh in milk, underfed for 10 weeks, overfed for two weeks and again underfed for a week.

No. 2 (1) was fed for 70 days an increasingly deficient ration, receiving for 8, 12, 18 and 32 days approximately a ⅞, a ⅘, a ¾ and a ⅔ ration. Her live weight shrunk 2 percent in 50 days, 5 percent in 54 days, 8 percent in 62 days, 11 percent in 66 days, and 13 percent in 70 days, falling off rapidly after being on the ⅔ ration for 10 days. She shrank in milk flow but 4 percent in the first 38 days, but during the 32 days on the ⅔ ration, she shrank in successive 8-day periods as compared with her initial yields, 2, 7, 15 and 27 percents. The quality varied. Total solids ranged from 14.3 to 14.6 percents in successive 8-day periods, except that near the end it sank to 14.1 percent. The fat percentages were relatively low, 4.42 percent for 8 days, hovered about 4.8 percent for 32 days and 4.65 percent for 24 days; then shot up to 5.58 percent for the final 8 days, coincident with a 38-pound live weight shrinkage. The total protein percentage, after the colostral effect was overcome, dropped in successive 8-day periods from 3.8 to 3.3 and in the last one to 3.01. The plane of protein intake of course dropped coincidently. On the average for the period it was but 1.5 pounds per 1,000 pounds live weight and for the last month was 1.3 pounds. The sugar-ash percentages were fairly constant.

No. 2 (2), during 17 days of decided overfeeding, in which a 1⅓ ration was eaten, following 70 days of underfeeding, rapidly increased her live weight, which was 7 percent larger at the end of the period than it was two weeks previous. The milk flow rapidly rebounded from 9.8 pounds to 10.3, 11.8, 12 and 12.7 pounds in successive 3- to 5-day periods. Fat percentages dropped profoundly and then rose again somewhat, and protein rose rapidly coincident with a nearly doubled protein intake. Sugar-ash figures remained constant. Gains as compared with the last 16 days on subnormal feeding were: 11 percent solids and fat, 10 percent protein, 14 percent; sugar-ash 8 percent.

No. 2 (3). When again underfed by 30 percent for seven days, neither live weight, milk yield nor quality was affected for five days, but during the last two days live weight dropped 25 pounds, milk yield 1.5 pounds and an upward trend in fat percentage began to be manifested.

### UNDERFEEDING FOLLOWED BY NORMAL FEEDING

No. 301, fresh in milk, underfed for a month and normally fed for a week.

No. 301 (1), fresh in milk, decidedly underfed for 36 days and then normally fed for a week, dropped off in live weight in successive 8-day periods, as compared with her weight immediately following calving, 7, 12, 16 and 17 percents and in milk flow, 1, 13, 28 and 34 percents. Except for the initial colostral effect, the quality of the milk remained quite uniform. She ate 1.6 pounds of digestible protein per 1,000 pounds live weight and put 40 percent of it into her milk flow.

No. 301 (2). When normally fed for six days, live weight had increased 3 percent and milk yield 6 percent during the fifth and sixth days. The total protein content of the milk slightly increased but otherwise quality remained unaffected.

No. 20, fresh in milk, greatly underfed for a month, underfed for two weeks, and less underfed for another two weeks.

No. 20 (1), fresh in milk, grievously underfed a ⅖ ration for 34 days, dropped off rapidly in live weight, 3, 7, 11 and 14 percents in successive 8-day periods, and in milk flow 0, 6, 14 and 9 percents, an average of 7 percent. After the colostral effect passed off, protein and sugar-ash percentages were reasonably constant; but the fat figure shot upwards. Giving normally a 4.8 percent milk, she gave from 4.9 to 7.2 percent milk, averaging 6 percent. Apparently, she poured her body substance into the milk pail in the form of fat. She ate 1.6 pounds of digestible protein per 1,000 pounds live weight and put about 45 percent of it into the milk pail.

No. 20 (2). When after three days of semi-starvation, she was fed a ¾ ration for 12 days, live weight increased 2 percent over the final weights of the previous period and she greatly increased her milk flow, giving 14 percent more than at calving, 20 percent more than in the average of the preceding period, and 22 percent more than at its close. The total protein and sugar-ash percentages were slightly and fat the percentage tremendously lowered. She gave 4.46 percent instead of 6 percent milk and 6 percent less fat than during the first period.

No. 20 (3). When, after 34 days on a ⅖ and 12 days on a ¾, she was fed for 16 days on a ⅞ ration, she gained 1 and 3 percents in live weight as compared with the two previous periods, maintained her recent high milk flow, lowering slightly—4.21—its fat content, other constituents remaining constant, giving 19 percent more milk and 12 percent less fat than during the semi-starvation period which was 40 days nearer calving.

### UNDERFEEDING

No. 206, 10 days in milk; greatly underfed for three weeks; considerably underfed for two weeks; slightly underfed for one week.

No. 206 (1), receiving only ⅖ of a normal ration for three weeks, dropped rapidly in live weight from day to day, having lost on the 6th, 12th, 18th and 22nd days 5, 10, 14 and 16 percents of her weight at calving. She maintained her milk yields, giving at the outset and in two 6-day and two 4-day periods 28.4, 31.6, 32.2, 30.1, 28.1 pounds, the average yields for the second and third weeks being identical with that of the first week. The colostral effect was manifest during the first week, after which time total protein, sugar and ash percentages were fairly constant. Her fat percentages (average 3.85 percent) were somewhat high of probable normality.

No. 206 (2). After 22 days of semi-starvation, being fed a ⅘ ration for two weeks and having gained one percent over her final weights in the previous period, she maintained the same milk flow as during the last 8 days of the previous period, fat and total protein percentages about 5 percent, ash 10 percent, sugar 9 percent, while total solid figures remained unchanged.

No. 206 (3), fed for 8 days a nearly normal ration, began rapidly to regain body weight, gaining 2 percent over the previous period and the latter part of the semi-starvation season. She promptly increased her milk flow, giving 8 percent more than in the previous period or at the close of the semi-starvation season. The total protein, sugar and ash percentages were not changed, but the fat percentages dropped 11 percent; hence she gave a little less total fat than during the preceding period.

The authors state that the most pronounced result of overfeeding was to cause the cow to gain weight; that "overfeeding exerted (no) influence towards abnormality in the composition of the milk" but that following abnormality in this respect due to sub-normal feeding "overfeeding restore(d) the abnormal composition to a normal one"; and that "only in certain cases * * * did (super-normal feeding) raise the flow of the milk and the influence in these cases was very limited."

They discuss the physiology of milk secretion in respect to the blood stimulus or "hormone" theory. They state that their findings indicate that "the secretion of milk is regulated by at least two factors * * * chemical and nervous * * * (the former being) the predominating stimulus immediately following parturition * * * for a period of time * * * fix(ing) the maximum milk flow for each individual * * * (and being) more or less independent of the plane of nutrition * * * (whereas the latter) is entirely dependent upon the plane of nutrition." They cite the prolonged heavy milk flow following parturition at the expense of body live weight on an inadequate food supply as an exhibition of the effect of the chemical stimulus which "it is not possible to increase * * * by means of an excess food supply"; and they point out that increasingly as lactation advances, the effect of the chemical stimulus is replaced by that of the nervous stimulus and that "as soon as (this) predominates, the milk flow is readily affected by a sub-normal plane of nutrition and can be partially restored * * * by increasing (this) plane."

In respect to the results of underfeeding, they state in general that live weights shrunk; that "immediately after parturition * * * the milk flow * * * (is maintained) at a nearly constant level under the most adverse conditions * * * (but that its) decline accompanies even moderate underfeeding when the lactation period has reached a certain stage," the reasons being indicated above. They indicate that "physiological underfeeding and reduction in the plane of nutrition from a high to a normal plane (results in) a marked increase in the fat percentage (especially in fat cows and) almost invariably (in) an actual increase in the yield of fat"; that following sub-normal feeding, sometimes richer, sometimes poorer, and sometimes unchanged quality in respect to fat percentages results: and that the protein and ash but not the milk sugar contents sometimes are affected.

The authors advance the hypothesis that the production of milk fat is controlled by lipase and other enzymes accelerating the synthesis of the mammary gland and is influenced by general metabolic activity.[1] *Mo. Sta. Rsch. Buls. 24, 25 (1916); Abstr. E. S. R. 35, pp. 774-775 (1916); 36, pp. 669-671 (1917).*

## 7. ABSTRACTS RELATING TO FEEDING TRIALS OF A MISCELLANEOUS CHARACTER

Jordan and Jenter (1897) fed a cow for 95 days with rations so treated as to reduce her total fat intake to ⅛ of a pound daily. Very considerable food changes induced no changes in quality. The nitrogen balance was studied. In this connection, the authors suggest that a cow giving 30 pounds of milk secretes therein about one pound protein; that if she is fed 2.5 pounds digestible protein, she does not seem to use the additional 1.5 pounds for necessary construction purposes; that the protein metabolism seems influenced in the main by protein supply and not by the quantity of milk solids secreted; and they advance the hypothesis that the notable influence of abundant supplies of digestible protein upon milk secretion is due to the stimulation of metabolic activity. *N. Y. (State) Sta. Bul. 132, (1897); Abstr. E. S. R. 9, pp. 1083-1085 (1898).*

Woll (1891) fed 20 cows two rations, differing only in that the one contained corn silage and the other corn fodder. Hay, bran and middlings comprised the residue of each ration. No analyses were made except for dry matter contents. The cows ate 10 percent more dry matter in the silage than in the fodder ration and made per unit of dry matter eaten 8 percent more milk and 6 percent more fat on the dry ration. The fat contents of the milk were not affected. However, losses in food values from methods of storage turned the scales in favor of the silage, 3 percent more milk being produced per unit of land area harvested as silage. *Wis. Sta. Rpt. 8, pp. 49-60 (1891); Abstr. E. S. R. 4, pp. 178-180 (1892).*

Woll (1892) fed 16 cows for three months by the reversal system, with a view of determining the comparative values of whole silage and stover silage plus the picked ear corn. The cows ate 3 percent more dry matter when on the whole silage ration and made 4 percent more milk and 7 percent more fat. Fodders and feeds do not seem to have been analyzed and no total solid determinations seem to have been made; neither are the digestible nutrient, digestible protein or nutritive ratio statements given. However, it is evident that relatively wide rations of closely similar nutritive ratios were fed and that the milk made on the whole-silage ration contained about 0.10 percent more fat than did that made on the stover-silage and plucked ear ration. *Wis. Sta. Rpt. 9, pp. 53-71 (1892); Abstr. E. S. R. 5. pp. 500-501 (1893).*

Woll (1912) has shown, using data secured from many records, that fat yields increase with average body weights of the cows and the feed units eaten. He explains this fact on the ground that "a large animal has a relatively smaller body surface than a small animal, (that) the radiation of heat from the former is therefore proportionately smaller than that from a small animal," and that, as a consequence, a larger proportion of the feed eaten by heavy cows is available for milk production. The cows approximating 900 pounds in weight and 1,010 pounds in weight ate, respectively, 100 and 108 units and produced 100 and 105 units of fat per 100 feed units.[1] *Soc. Prom. Agr. Sci. Proc. 33, pp. 23-28 (1912); Abstr. E. S. R. 29, pp. 374-375 (1913);* also *Wis. Sta. Bul. 226 (1912); Abstr. E. S. R. 28, p. 74 (1913); Wis. Sta. Rsch. Bul. 26, pp. 55-135 (1912); Abstr. E. S. R. 28, pp. 272-274 (1913).*

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[1] The studies reviewed in this abstract have little direct relation to the digestible protein problem as such but are so fundamental that their inclusion seems justified.

Haecker (1894) compared divers groups of cows, the groupings being made on its basis of conformation—those of blocky, plump form (3 in number); of a less marked fleshy trend (4 in number); of a spare, angular form lacking medial depth (3 in number); and of a spare angular form with medial depth (12 in number). Their food intakes and milk outputs as groups during a winter season were:

| | Blocky | Less blocky | Spare lacking depth | Spare and deep |
|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. |
| Average weights................ | 1240 | 945 | 875 | 930± |
| Fat yields (during winter)...... | 117 | 135 | 134 | 155 |
| Dry matter usage (daily) | | | | |
| Total ...................... | 20.8 | 20.4 | 20. | 21.9 |
| Per 1,000 lbs., body weight.. | 16.7 | 21. | 23. | 23.6 |
| Per lb. of fat................ | 31.3 | 26.4 | 25.5 | 21.2 |
| Lbs. fat per 100 lbs. dry matter.. | 3.2 | 3.8 | 3.9 | 4.7 |

The author holds that "the cost of producing butter depended more upon the type of cow than upon breed or size," and that "the chief cause of (yield) variation was . . . difference in conformation." *Minn. Sta. Buls. 35, pp. 54-64 (1894) copied in 67, pp. 458-466 (1900); Abstr. E. S. R. 6, pp. 925-926 (1895).*

Haecker (1908) analyzed the records made by 70 registered cows (5 Brown Swiss, 15 Holstein and 25 each Jersey and Shorthorn) for 120 days in 1904 at the St. Louis Exposition. They ate green corn, silage, alfalfa hay, a little clover hay, green clover and cow peas as roughages; and malt sprouts, hominy feed, gluten feed, corn hearts, bran, oil meal, distillers' dried grains, ground oats, cottonseed meal, corn meal and a proprietary ration known as "Union Grains" as concentrates. The cows ate enormously and yielded profusely, the average daily records for 120 days being:

| Breed | Number of cows | Live weight | Total dry matter | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Milk yield | Total solids | Fat | Total solids | Fat | Pounds digestible nutrients to make | | | Proportion of digestible nutrients in | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 100 pounds milk | 1 pound total solids | 1 pound fat | Roughage | Concentrates |
| | | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | lbs. | lbs. | lbs. | lbs. | lbs. | % | % |
| Brown Swiss.. | 5 | 1329 | 38.4 | 4.9 | 24.1 | 44.2 | 12.48 | 3.62 | 5.52 | 1.60 | 61.7 | 3.6 | 16.9 | 40 | 60 |
| Holstein.. | 15 | 1289 | 40.2 | 5.1 | 22. | 53.4 | 11.37 | 3.42 | 6.07 | 1.83 | 50.7 | 3.3 | 14.8 | 50 | 50 |
| Jersey ... | 25 | 948 | 35.6 | 4.9 | 19.4 | 41.5 | 13.42 | 4.67 | 5.57 | 1.94 | 56.2 | 3. | 12.1 | 51 | 49 |
| Shorthorn .. | 25 | 1257 | 30.8 | 4.4 | 17.2 | 35.2 | 12.30 | 3.68 | 4.33 | 1.30 | 57.2 | 3.4 | 15.5 | 41 | 59 |

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[1] The results secured in the Vermont trials which are discussed in this bulletin are quite in accord with Woll's findings.

In economy of production the breeds ranked: solids and fat, Jersey, Holstein, Shorthorn, Brown Swiss; milk, Holstein, Jersey, Shorthorn, Brown Swiss. The physiological reason for the lower production cost of a pound of Jersey fat is that there were but 1.9 pounds solids-not-fat produced coincident therewith, whereas the proportions with the other herds were 1:2.3, 2.3 and 2.5. Obviously it takes more food to produce more solids. The cows apparently ate on the average about 25 percent more protein and from 20 to 30 percent more total nutrients than was needed for milk, maintenance and growth. On the theory that excess protein acts as a milk stimulus it was perhaps wise thus to force the cows. However, Haecker says, in this connection, that "the cows received nearly twice as much protein as was needed"; that excessive protein intake "is a fruitful source of barrenness, shy breeding, rheumatism, gout and other disorders"; that "heavy feeding of highly nitrogenous feeds has injured many * * * great cows and their progeny" because of "abnormal stimulation and development of the digestive and mammary organs." *Minn. Sta. Bul. 106, pp. 147-169 (1908); Abstr. E. S. R. 19, pp. 1177-1178 (1908).*

Bartlett (1895) compared wheat and corn meals, using six cows during nine weeks and the reversal method, feeding timothy hay and cottonseed meal with the two varients. The wheat meal value furnished somewhat more digestible protein than its competitor. The two rations exhibited nutritive ratios of 1:7.1 and 1:8.7. The wheat meal proved as good or better than corn meal as a milk maker and better as a producer of body weight. *Me. Sta. Rpt. 11, pp. 24-30 (1895); cited E. S. R. 8, pp. 825-826 (1897).*

Spier (1897) holds—as a result of studying data secured with 8 cows fed a variety of food combinations for somewhat more than a year—that, "provided extremes are avoided, the dry matter of food seems to be the principal controlling factor in the production of milk or increase of live weight and is of greater importance than the albuminoid (nutritive) ratio." *Trans. Highland and Agr. Soc. Scotland 5, 9, pp. 296-338 (1897); Abstr. E. S. R. 10, p. 486 (1898).*

Kellner and Andra (1898) fed to 24 cows in 3-week periods basal rations of hay, straw, bran, linseed, cottonseed and peanut meals, to which were added either sugar beets or beet diffusion residues. The same amounts of digestible nutrients were furnished in each ration. More milk and fat were yielded on the residue ration than on the beet ration and body weights were increased. The solid and fat percentages were not altered. *Landw. Vers. Stat. 49, 6, pp. 402-418 (1898); Abstr. E. S. R. 10, pp. 587-588 (1899).*

Kellner (1907) reports a comprehensive feeding trial dealing with the influence of food fat on milk yield in which, apparently, 200 cows were used and both the reversal and the group systems of trials were employed. The substitution of fat for equivalent amounts of carbohydrates was disadvantageous, both as regards yield and quality. *Illus. Landw. Ztg. 27, 43, pp. 387-388; 44, pp. 397-399 (1907); Molk Ztg. 21, 25, pp. 687-690 (1907); Abstr. E. S. R. 19, p. 75 (1907).*

Lindsey (1904) fed; 6 cows for 10 weeks by the reversal method, with hay, bran and, either, distillers' dried grains or gluten feed, the rations carrying 3 pounds of digestible protein, 15.2 to 15.6 pounds of total digestible nutrients and nutritive ratios of 1:4.4 and 1:4.5; 7 cows for 9 weeks by the reversal method on hay, silage, gluten feed, either brewers' dried grains or bran, the rations carrying 2.4 or 2.1 pounds of digestible protein, 14.5 to 14.7 pounds of total digestible nutrients and nutritive ratios of 1:5.5 and 1:6.3 respectively; and 4 cows for 6 weeks by the reversal system on hay, bran, corn meal and, either malt sprouts and gluten feed or gluten feed alone, the rations carrying 2.5 pounds of digestible protein, 14.5-14.8 pounds total digestible nutrients and nutritive ratios of 1:5. The distillers' grains proved full better than the gluten feed, making 5 to 6 percent more milk and fat; the brewers' grains somewhat better than the bran, making from 1 to 2 percent more milk, total solids and fat; while malt sprouts and the gluten feed seemed to be on a parity. *Mass. Sta. Bul. 94 (1904); Abstr. E. S. R. 16, pp. 87-88 (1904).*

Lindsey (1912) fed six cows by the reversal method during 5-week periods on rations of hay, bran, cottonseed meal and either corn meal or dried beet pulp; then, during 5-week periods, on hay, bran, cottonseed meal and either corn meal or molasses-beet pulp; and four other cows during 4-week periods on hay, bran and either corn meal or oats.

The nutrient intake and production data were as follows:

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1 : | lbs. | % | % | lbs. | lbs. |
| Corn meal | 21.1 | 13.2 | 1.57 | 12.3 | 7.8 | 18.8 | 14.58 | 5.46 | 2.74 | 1.02 |
| Dried beet pulp | 21.3 | 13. | 1.54 | 11.9 | 7.7 | 19.1 | 14.54 | 5.37 | 2.78 | 1.03 |
| Corn meal | 20.9 | 13.1 | 1.5 | 12.2 | 8.2 | 19.9 | 14.67 | 5.58 | 2.92 | 1.11 |
| Molasses-beet pulp | 21. | 12.9 | 1.59 | 11.7 | 7.4 | 19.3 | 14.52 | 5.44 | 2.80 | 1.05 |
| Corn meal | 23.8 | 14.7 | 1.6 | 13.8 | 8.6 | 19.2 | 14.56 | 5.72 | 2.79 | 1.09 |
| Oats | 23.7 | 14. | 1.77 | 12.9 | 7.2 | 19. | 14.42 | 5.71 | 2.74 | 1.09 |

As compared with the corn meal ration: The dried beet pulp ration made 2 percent more milk and total solids and 1 percent more fat; the molasses-beet pulp ration 3 percent less milk, 4 percent less total solids and 5 percent less fat; and the oats ration 1 percent less milk, 2 percent less total solids and the same amount of fat. No changes in live weight or quality of milk were noted, which were to be ascribed to the feeding. *Mass. Sta. Rpt. 25, pp. 129-153 (1912); Abstr. E. S. R. 30, p. 176 (1914).*

Lane, Billings or Cook (1899-1915), during a period covering about 15 years, conducted feeding trials, the results of some of which seem to have pertinence in this connection. The results secured in many of the earlier trials are inapplicable because the feeding periods were less than three weeks in length.

1. Four cows were fed for two months on a hay, silage, bran, dried brewers' grains and linseed meal ration (20.9 pounds total dry matter, 2.3 pounds digestible protein, 12.3 pounds digestible carbohydrates and fat (x 2¼); nutritive ratio 1:5.3) and on a hay, stover and corn meal ration (21, 1, 13.4 and 1:13.5). A third more milk and three-eighths more fat were produced on the first ration. One cow made richer milk on the poorer ration,

one much richer milk on the better ration and two gave essentially an unchanged quality. Body weights were not maintained by the wide ration.

2. Four 1,000-pound cows were fed for two months on rations of silage, mixed hay and cottonseed meal and either alfalfa hay or bran and brewers' dried grains. The rations furnished 25.6 and 22.8 pounds of total dry matter and 3.4 and 3.5 pounds of digestible protein; nutritive ratios being 1:5.6 and 1:5.4. The latter ration yielded 5 percent more milk and 7 percent more fat. The fat percentages were not materially affected. The cows were not weighed.

3. Four 1,000-pound cows were fed for ten weeks on rations of silage, mixed hay, bran and either cob meal or brewers' dried grains and cottonseed meal. The rations furnished 22.7 and 23.1 pounds of total dry matter, 1.6 and 2.6 pounds digestible protein, 14.4 and 13.7 pounds of digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:8.9 and 1:5.4. The latter ration made 13 percent more milk and 15 percent more fat. The fat percentages were not affected. Body weights were diversely influenced, two cows gaining on one and two on the other ration.

4. Eight cows were fed four months on rations containing silage and either alfalfa hay or corn stover, bran, distillers' dried grains and cottonseed meal. The rations furnished 27 and 22.5 pounds of total dry matter, 2.5 and 2.4 pounds digestible protein, 16.3 and 16.3 pounds of digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:6.5 and 1:6.9. The latter ration made 21 percent more milk and fat. The fat percentage was not changed. The body weights were not affected.

5. Four cows were fed two months on silage and stover, bran and cottonseed meal, and either gluten feed or distillers' dried grains. The rations furnished 23.3 and 23.3 pounds of total dry matter, 2.4 and 2.4 pounds digestible protein, 17.2 and 16.7 pounds digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:6.2 and 1:6.3. The latter ration made more body weight and from two to three percent more milk and fat. The fat percentages were not affected.

Eight cows were fed by the reversal system, bran, cottonseed meal and distillers' dried grains being replaced by alfalfa hay. The digestible nutrient contents of the two rations were closely alike. The nutritive ratios were 1:6.8 and 2.4 and 2.5 pounds of digestible protein and 16.3 pounds of digestible carbohydrates and fat (x 2¼) were furnished. The roughage ration yielded only five-sixths as much milk and butter fat as did its concentrate competitor. Body weights were not materially affected. The author states that it seems "fair to conclude that a continuous feeding of a ration made up entirely of roughage will not have the same nutritive effect as a ration containing more or less fine feeds"—which he ascribes to the effect of the large amount of crude fiber reducing the production value of a unit of digestible nutrients.

6. Four cows were fed for three months on silage, oat and pea hay and stover and either oats, bran, gluten feed and oilmeal and dried beet pulp or distillers' dried grains, bran and dried beet pulp. The rations furnished 24.1 and 23.1 pounds of total dry matter, 2.3 and 2.5 pounds of digestible protein, 14.4 and 14.3 pounds of digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:6.2 and 1:5.7 (erroneously stated in the tabular matter and text of the original bulletin as 1:5). The latter ration produced 5 percent more fat but 1 percent less milk than its competitor, the fat

percentages of the milk being increased by 0.3 percent. It has frequently been noted that distillers' dried grains sometimes exert this peculiar influence.

7. Four cows were fed for three months on alfalfa hay, silage, stover, cottonseed meal and either cob or corn meal. The rations furnished 22.5 and 22.7 pounds of total dry matter, 1.6 and 1.7 pounds digestible protein and 13.2 and 13.7 therms energy; nutritive ratios being about: 8.2 and 1:8.2.

The latter ration made 5 percent more milk and 4 percent more fat than the former. Live weights were unchanged in three instances and increased 10 percent in one; but there was no apparent relation between change of ration and this result.

8. Sixteen cows were fed for 100 days on silage, alfalfa and oat and pea hays, dried beet pulp, cob meal, and either soy bean or cottonseed meals. Soiling crops were also fed to all the cows during the first half of the trial. The rations furnished 25.2 and 25.7 pounds total dry matter, 2.6 and 3 pounds digestible protein, 14.9 and 14.7 pounds digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:5.7 and 1:5. The former ration yielded 2 percent more milk and 4 percent more fat, and a slightly richer milk. Body weights were not affected.

9. Fourteen cows were fed for 100 days rations containing silage, dried beet pulp, corn and cottonseed meal, gluten feed, distillers' dried grains and bran, and either alfalfa hay or sundry soiling crops. The rations furnished 26.8 and 23.9 pounds total dry matter, 2.7 and 2.2 pounds digestible protein, 13.6 and 13.9 pounds of digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:5.1 and 1:6.3. From 1 to 2 percent more milk and fat were made on the latter ration. Fat percentages and body weights were unchanged.

10. Twelve cows were fed for 100 days on rations containing silage, alfalfa hay and either cob meal, cut alfalfa, molasses and soy bean meal, or corn meal, dried beet pulp, gluten feed, bran and cottonseed meal. The rations furnished 27.7 and 27.5 pounds of total dry matter, 2.6 and 2.6 pounds digestible protein, 16.4 and 16.5 pounds of digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:6.3 and 1:6.3. The yields on the two rations were identical and the quality of the milk identical. (The tabular matter and text do not bear out this statement but they contain obvious errors.) The body weights indicate a slight preference for the latter ration.

*N. J. Stas. (1) Bul. 137, pp. 12-17 (1899); (2) Bul. 148, pp. 15-21 (1901); (3) Rpt. 21, pp. 266-273 (1900); (4) Bul. 190, pp. 19-28 (1905); (5) Bul. 204, pp. 4-24 (1907); (6) Rpt. 28, pp. 39-49 (1907); (7) Rpt. 33, pp. 159-169 (1912); (8) Rpt. 34, pp. 293-316 (1913); (9) Rpt. 35, pp. 142-146 (1914); (10) Rpt. 36, pp. 125-130 (1915). Abstr. E. S. R. (1) 11, pp. 884-885 (1900); (2) 13, p. 176 (1901); (3) 13, p. 778 (1902); (4) 17, pp. 900-901 (1906); (5) 19, p. 272 (1907); (6) 19, pp. 1073-1074 (1908); (7) 30, p. 375 (1914); (8) 32, pp. 573-574 (1915); (9) 34, pp. 180-181 (1916); (10) 36, pp. 871-872 (1917).*

Hayward (1900) fed nine cows by the combined reversal-group system, six actually being fed the trial rations. Hay, cottonseed meal and linseed meal were fed continuously with corn meal, rye meal and Quaker oat feed as the varients.

The food consumption and milk production data for the cows fed in the strictly reversal way were as follows:

| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (x 2¼) | Nutritive ratios | Milk | Total solids | Fat | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | 1 : | lbs. | % | % | lbs. | lbs. |
| On corn meal .. | 17.6 | 13. | 2.12 | 10.9 | 5.1 | 17.3 | 13.45 | 4.45 | 2.33 | 0.77 |
| On rye meal | 18.9 | 13.3 | 2.15 | 11.2 | 5.2 | 16.7 | 13.27 | 4.41 | 2.21 | 0.73 |
| Rye ± corn .. | + 1.3 | + 0.3 | +0.02 | + 0.3 | .. | — 0.6 | — 0.18 | —0.04 | —0.12 | —0.04 |
| Percents .. | + 8 | + 2 | +1 | + 3 | .. | — 4 | — 1 | —1 | —5 | —5 |
| On corn meal .. | 18.9 | 13.8 | 2.18 | 11.3 | 5.3 | 17.9 | 13.25 | 4.44 | 2.37 | 0.80 |
| On Q. O. feed .. | 19.2 | 12.9 | 2.12 | 10.8 | 5.1 | 16.7 | 13.28 | 4.55 | 2.21 | 0.76 |
| Rye ± corn .. | + 0.3 | — 0.9 | —0.06 | — 0.5 | .. | — 1.2 | + 0.03 | +0.11 | —0.16 | —0.04 |
| Percents .. | + 2 | — 7 | —3 | — 4 | .. | — 7 | 0 | +3 | —7 | —5 |

Taking the above data into account in connection with those furnished by the cows fed continuously on the corn meal ration, it seems fair to say that, though eating a little more digestible nutrients, the cows fed the rye meal ration made about 4 percent less milk and solids and 3 percent less fat; and that those fed the Quaker oats ration eating 7 percent less digestible nutrients, made 6 percent less milk and solids and 3 percent less fat than, in each instance, was made on the corn meal ration. Live weights did not vary materially. *Pa. Sta. Bul. 52 (1900); Abstr. E. S. R. 12, pp. 678-679 (1901).*

Hayward (1902) fed eight cows for 120 days under such conditions that half of them were fed a uniform ration for the entire term, while the other half were fed first the same uniform ration for 40 days, then, two rations of equivalent food values, changed every 5 days back and forth during 40 days, and, finally, the original uniform ration during the next 40 days. The varied diet showed no influence whatsoever on the milk flow. *Pa. Sta. Rpt. 1902, pp. 314-320; Abstr. E. S. R. 15, p. 18 (1904).*

Steinbruch (1901) discussing a few short time trials with four cows and reviewing literature, states that, as a rule, bovine individuality rather than feed change is the controlling factor in milk production, the effect of the latter item often being relatively a minor matter. He further states that food given in excessive amounts contributes, so far as the excess is concerned, to body weight rather than to increased milk yields. *Ber. Physiol. Lab. Landw. Inst. Halle 3, 15, pp. 104-168 (1901); Abstr. E. S. R. 13, p. 685 (1902).*

Soule and Barnes (1902) compared two proteinous hays, cow-pea and alfalfa, with both bran and cottonseed meal during two seasons. Twelve cows were fed for 120 days in three groups each year. The competing rations were silage, cottonseed meal and bran; silage, cottonseed meal and cow-pea hay; silage, bran and cow-pea hay; silage, bran and cottonseed meal; silage, alfalfa hay and cottonseed meal; silage, alfalfa hay and bran.

It is not clear whether analyses of fodders and feeds were made or "averages" were used, but apparently the latter procedure was followed. There seems to have been fed in the six rations in the order indicated, in terms of total dry matter, digestible dry matter and digestible protein per cow daily (averaging to weigh in the first trial 830 to 880 pounds and in the latter 800) 20.4, 20, 21.6, 18.9, 20.2 and 20.5 pounds; 13.9, 12.6, 12.7, 12.1, 12.6 and 12.5 pounds; 2.7, 2.61, 2.13, 2.37, 2.58 and 1.95 pounds; nutritive ratios being 1:4.5, 4.2, 4.8, 4.5, 4.2 and 5.8.

Live weight changes were not deemed to be significant. The fact that the group method of comparison alone was used without being checked by the reversal method naturally affects the reliability of the results and conclusions. However, when cottonseed meal was omitted the least product was made each year; when both concentrates were included much the most product was made one year and as much as when the cottonseed-alfalfa ration was fed the second year. The relative production indexes on the basis of 100 for the six rations in order stated, were: 100, 89, 93; 100, 100, 82. The authors maintain that these two home-grown leguminous roughages can be substituted to advantage for expensive purchased concentrates. *Tenn. Sta. Buls. 15, 4 (1902); 17, 4 (1904); Abstr. E. S. R. 14, pp. 605-606 (1903); 16, pp. 694-695 (1905).*

Soule (1905) fed 24 cows for four months, without reversal, rations containing silage, either hay or corn stover, cob meal and either cottonseed meal or gluten meal. It is difficult to analyze his discursive statements, but apparently the productive powers of the two concentrates were closely alike. *Va. Sta. Bul. 156 (1905); Abstr. E. S. R. 17, p. 900 (1906).*

Soule, Fain and Jarnagin (1907) fed 4 groups of 4 cows each for 140 days, using the reversal system. They fed corn stover, silage, millet hay as roughages, cob meal, cottonseed meal and bran in varying proportions as concentrates. During the initial and final 30-day periods, all groups ate closely similar rations, containing of total dry matter, digestible protein and digestible carbohydrates and fat (x 2¼) respectively 22. to 26.5, 1.63 to 2.05, 13.8 to 16.6 pounds, with nutritive ratios closely alike 1:7.9 to 1:8.2 (7 instances) and 1:8.8 (one instance). During the intermediary 80-day period the rations varied widely, in two groups being more and in one less proteinous in character, remaining unchanged in the other instance, the nutrient data being 21.5, 25, 24.5 and 23.5; 2.21, 2.39, 1.95 and 1.49; 12.8, 15.3, 15.4 and 15.2; with nutritive ratios 1:5.8, 1:6.4, 1:7.9 and 1:10.2.

The discussion seems somewhat obscure. However, a study of the data shows that the cows fed the narrow rations (1:6) during the intermediary period made approximately 3 percent more milk, 4 percent more solids and 8 percent more fat than when fed the wider rations (1:8) and that the milk was slightly richer in fat (0.16 percent); that the cows fed an unchanged ration made 2 percent more milk and one percent more fat; and the cows fed the wider ration (1:10) made 4 percent less milk, 5 percent less solids and 2 percent less fat. Live weights did not seem to be materially influenced one way or the other. The authors hold that satisfactory results may be attained if less digestible dry matter and protein are fed than are provided by the Lehmann standard. *Va. Sta. Bul. 169 (1907); Abstr. E. S. R. 19, p. 571 (1907).*

Doane (1904) fed to 15 cows during 8 weeks two rations each with narrow nutritive ratios of 1:5.5 and 1:5.3; the one an alfalfa hay and corn meal, the other a silage and purchased grain mixture (linseed and gluten meals and malt sprouts). The former outclassed the latter. An alfalfa and silage ration of a 1:5.5 nutritive ratio did not succeed as well as the silage-grain ration above noted. No analyses seem to have been made. *Md. Sta., Bul. 98, pp. 59-63 (1904); Abstr. E. S. R. 16, p. 693 (1905).*

The results secured elsewhere by one of us (C. E. B., 1906) tend to show that facility of digestion of foods is an important factor in feeding, that less digestible nutrients in concentrates are required for maintenance or production than in hay, because less of the food energy is used in processes of digestion and assimilation.[1] *Conn. (Storrs) Sta. Bul. 43 (1906); Abstr. E. S. R. 18, p. 972 (1907).*

Clark (1906) fed 24 cows, by the reversal system, alfalfa, bran and middlings so combined that with one lot a high roughage-low concentrate ration was used, whereas with the other a low roughage-high concentrate combination was employed. The latter combination always produced the larger milk and fat yields. No analyses were made and no statements are vouchsafed which enable one to determine the relation between digestible nutrient consumption and production. *Utah Sta. Bul. 101, pp. 179-188 (1906); Abstr. E. S. R. 19, pp. 369-370 (1907).*

Hansen (1906) fed 16 cows during about five months, in each of two years and deduces from the results secured that feeding stuffs exert a specific influence on milk production independent of their nutrient contents, which is shown sometimes in the milk yields but more often in the fat content of the milk; and he cites the effects of divers feeds in this respect. *Landw. Jahrb., 35, 1-2, pp. 125-158, sup. 4, pp. 327-369 (1906); Abstr. E. S. R. 17, p. 901 (1906); 18, pp. 765-766 (1907).*

Hummell (1906) tested the validity of certain standard digestion coefficients by comparing the results obtained by digestion experiments conducted by himself on six steers of widely different types. The results were calculated, using actual analyses and the determined coefficients as well as by using average analyses and the standard coefficients. The agreement was in all cases a "reasonably close" one and tends to confirm one's faith in the essential accuracy of digestion coefficients. *Minn. Sta. Bul. 99, pp. 121-132 (1906); Abstr. E. S. R. 18, pp. 969-970 (1906).*

Buschmann (1908), feeding 22 cows, replaced cocoanut cake by sunflower cake to the detriment of both the milk yield and its fat content. A similar result was secured with 7 cows. When sunflower cake replaced cottonseed meal, milk yields were depressed; when cocoanut meal replaced cottonseed meal, milk yields were increased and fat percentages decreased. *Landw. Jahrb., 37, 6, pp. 899-959 (1908); Abstr. E. S. R. 20, p. 1175 (1909).*

Müller (1909) fed two cows during about 20 weeks on a basal ration containing no roughage—other than beets—to which rye straw was added or withdrawn in whole or in part at various times. Concentrates were added coincident to such withdrawal in order to maintain an equilibrium of digestible nutrients. No effect one way or another was observed on the milk flow or its composition or upon the health of the cows. *Ber. Physiol. Lab. u. Vers. Anst. Landw. Inst. Halle, 19, pp. 43-125 (1909). Abstr. E. S. R. 22, p. 778 (1910).*

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[1] This consideration was carefully kept in mind in the original shaping of the weight trials and the proportions of dry and succulent roughages and of concentrates kept as nearly uniform as possible throughout the long series of years.

Eckles and Reed (1910) fed to two half-sisters, registered Jerseys, while farrow, rations of identical composition, so regulated in quantity as to maintain a uniform weight. One cow ate 75 percent more than the other and made 2.7 percent more product. The maintenance usage of each cow was determined and digestion trials made, which furnished essentially identical figures. One used 35 percent, the other 56 percent, of her food for maintenance; and therein is to be found the answer to the riddle. The one kept herself at a low cost, the other used too much to keep her vital machinery in motion. A trial of this sort furnishes food for thought to the advocates of the group method of experimentation. *Mo. Sta. Rsch. Bul. 2 (1910); Abstr. E. S. R. 24, p. 76 (1911).*

Michels (1910) fed 13 cows for 12 weeks rations with nutritive ratios approximating either 1:4 or 1:5.7. The roughages and concentrates were similar in each case. Each ration was what usually would be deemed a narrow, and one an excessively narrow, ration. Milk yields were practically identical, but the very narrow ration made richer milk, thus increasing the fat yields by 8 percent. Body weights were not changed.

Michels also fed cottonseed and linseed meals against each other. No statement is made as to the nutritive ratios which, however, clearly were relatively narrow. No changes in milk or fat yields were noted which were beyond the limits of experimental error. Live weights were not materially affected. *No. Car. Sta. Bul. 213 (1910); Abstr. E. S. R. 25, pp. 777-778 (1913).*

Van Norman and one of us (A. A. B.) (1911) fed equivalent amounts of digestible nutrients during three years of trial to two groups of 12 cows each, the nutrients in the one instance being supplied in a bulky and in the other in a concentrated form.

Although a very large amount of work was done and an immense amount of tabular matter is presented, apparently no analyses whatever were made. either of roughages or concentrates. The total usage of dry matter, of total nutrients and of "protein"—presumably digestible protein—are stated, "computed from data in Farmers' Bulletin 22 of the United States Department of Agriculture." These data were used for the reason that "it was found by analysis that the proportion of dry matter varied but slightly from that given in the bulletin."[1]

It appears that body weights were not materially affected to the advantage of either ration; that a pound of nutrients in grain was equivalent to 3.47 pounds of nutrients in roughage; and that the cost expressed in terms of nutrients of making a pound of milk was 9.2 percent less for the group fed a concentrated ration than for that fed a bulky ration.[2] *Pa. Sta. Rpt. pp. 268-307 (1911); Abstr. E. S. R. 28, p. 174 (1913).*

Caldwell (1913) during two seasons fed two groups of cows, consisting of 5 and 6 and of 4 and 5 individuals, rations of silage, corn stover, cottonseed meal, corn meal and bran the first year; and of silage, soy bean hay, cottonseed meal and corn meal the second year; the daily nutrient consumption being 2.8 and 2.8 pounds digestible protein, 18.9 and 18 pounds digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:6.7 and 1:6.5 the first year; and 2.9 and 2.9, 20.4 and 20., and 1:6.8 and 1:7 the second year. The comparative test feeding periods were 60 and 77 days long. The replacement of cottonseed meal by soy bean hay was the crux of the trial. The soy bean hay ration made 6 percent less milk and 2 percent less fat, but the milk was 0.2 percent richer in fat in the first test; whereas in the second test the soy bean hay ration made 3 percent less milk but 6 percent more fat, the fat percentages being 0.4 percent apart. In this latter instance the cows gave consistently different qualities of milk. Live weights were maintained in all cases.

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[1] In view of the very large amount of work involved in these Pennsylvania trials the writer (J. L. H.) deems it unfortunate that more serious consideration was not given to so fundamental a matter as the analyses of the fodders and feeds.

[2] Appreciating this possibility from the outset, care was taken in planning the longtime Vermont trials now under survey to make the proportion of roughages and concentrates in the several rations, as well as their total energy contents, as nearly as might be identical; hence this particular source of error was not a disturbing factor.

A similar trial was made with two groups of 6 cows, each fed silage, corn stover, cottonseed meal, corn meal and bran against silage, alfalfa hay and corn meal for 56 days, the nutrient consumption being 18.3 and 20.7 pounds total dry matter, 2.7 and 2.5 pounds digestible protein, 15.4 and 17.5 pounds of digestible carbohydrates and fat (x 2¼), nutritive ratios being 1:5.7 and 1:7. The wider ration made 7 percent more milk and 3 percent less fat, the milks being 0.5 percent apart in fat percentages. It will be noted, however, that the alfalfa-fed cows ate 12 percent more total dry matter and 10 percent more digestible dry matter and consequently made less milk and much less fat per unit of ingested food. The alfalfa-fed cows increased in live weight; their competitors barely held their own. *Ohio Sta. Bul. 267 (1913); Abstr. E. S. R. 32, pp. 265-266 (1915).*

Hart, Steenbock and Fuller (1913) have pointed out that long continued and heavy milk production may entail as high a calcium outgo as intake if not, indeed, higher, unless legume hays are included in the ration or calcium is supplied in other forms.[1] *Jour. Biol. Chem., 14, 2, pp. 59-73 (1913); Abstr. E. S. R. 29, pp. 65-66 (1913); Wisc. Sta., Rsch. Bul. 30 (1914); Abstr. E. S. R. 30, pp. 867-868 (1915).*

Van Norman and Davis (1912) fed to 6 lots of three cows each, by the reversal system, three grain mixtures each having the same ratio of digestible protein and energy. They found one mixture essentially as efficient as another in respect to production. *Pa. Sta. Rpt. 1912, pp. 266-267; Abstr. E. S. R. 34, p. 181 (1916).*

Hart and Humphrey (1914) fed alfalfa hay against corn meal, using the reversal system, to Holstein cows in full milk. Corn meal, gluten feed and corn stover; and alfalfa hay and corn starch; were used, the total consumption of all nutrients in each ration being essentially alike. The nitrogen of the alfalfa hay proved as effective a milk maker as that in the corn kernel. When fed to growing heifers, the utilization for growth of nitrogen from alfalfa hay was as efficient as from the corn kernel. *Wis. Sta. Rsch. Bul. 33, pp. 87-119 (1914); also Jour. Biol. Chem. 19, 1, pp. 127-140 (1914); Abstr. E. S. R. 32, pp. 74-75, pp. 863-864, 871 (1915).*

Foster and Latta (1915) fed alfalfa, corn and bran against alfalfa; cottonseed meal and bran in different proportions with corn meal and alfalfa hay; alfalfa hay and grain against the same ration plus silage; using the group system with from 3 to 6 cows in a group. No analyses of fodders, feeds or milk (except for butter fat) seem to have been made. Corn and bran, 6 to 8 pounds, replaced 5½ pounds alfalfa hay and increased milk and fat production 12 percent. A slight increase in the amount of cottonseed meal fed increased production 3 percent. The addition of silage did not result in increased production. *New Mex. Bul. 98 (1915); Abstr. E. S. R. 33, pp. 872-873 (1915).*

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[1] Clover entered more or less into the hay supply in the Vermont trials discussed in this bulletin, although the amount furnished was not very large. Whether the cows did or did not suffer in respect to calcium usage cannot be said, but a careful study of the ash contents of the several rations and of the milk yields leads the writer to believe that no serious calcium drainage occurred.

Putney and Larsen (1915) discuss nitrogen studies using 18 cows during two years. Digestion trials were carried on and the nitrogen balance determined. Nitrogen utilization was 62 percent the first and 50 percent the second year. No attention was paid to the amount of digestible protein feed nor were definite conclusions hazarded as to protein requirements. However, the statement is made that the Eckles standards are deemed safe guides in practical feeding. Notable increases in the percentage and amount of urinal nitrogen was observed when rations were fed which were relatively rich in that element. *Pa. Sta. Rpt. (1915), pp. 250-293; Abstr. E. S. R. 38, pp. 73-74 (1918).*

Larsen, Hungerford and Bailey (1917) studying the rôle of water in a cow's ration found that digestion coefficients, notably that of crude fiber, were increased by infrequent drinking or by insufficient drinking and that, furthermore, after the cows had been on a ration for a month or more, its crude fiber content was more completely digested than during the initial month.[1] *So. Dak. Sta. Bul. 175 (1917); Abstr. E. S. R. 38, pp. 374-375 (1918).*

Hunziker and Caldwell (1917) for six months fed three lots of cows each by the combined group-reversal system—using six different rations designed to compare cottonseed and linseed meals, gluten feed, alfalfa and soy bean hays. The six grain rations had uniform nutritive ratios, those of the combined roughage-concentrate rations when alfalfa hay was fed averaging 1:7.8 and when soy bean hay was fed averaging 1:6.9. When on the alfalfa hay ration the cows averaged to give 7 percent more milk and 1 percent more fat than they did when fed the narrower soy bean hay ration. *Ind. Sta. Bul. 203 (1917); Abstr. E. S. R. 18, pp. 375-376 (1918).*

Arnett, Joseph and Tretsven (1917, 1919) fed two lots of 7 cows each by the reversal method rations designed to determine the value of sunflower silage. Thirty-four pounds of the latter fed daily replaced 9 pounds of clover hay. The ration containing the silage made 3 percent more milk and 5 percent more fat than that containing no silage.

They also fed 2 lots of 8 cows each, comparing sunflower silage and alfalfa hay with substantially equivalent results, when 60 percent of the hay was replaced by the silage, which was held to possess equivalence to alfalfa in the ratio of 2.83 to 1 or, on the dry matter basis, 0.71 to 1. They fed two groups of 8 cows each silage made when 1/3 and when 9/10 of the plants were in bloom, without definite results. They found the green plant to be a satisfactory soiling crop. *Mont. Sta. Buls. 118 (1917), pp. 73-80, 131, (1919) pp. 13-29; Abstr. E. S. R. 39, p. 182 (1918), 43, pp. 68-69 (1920).*

Lindsey and Beal (1918) compared corn bran and wheat bran fed to 14 cows by the reversal system, four pounds of each being fed each cow.

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[1] The cows used in the Vermont trials were watered twice a day and their water usages recorded. They had all they wanted. No material differences in water usage were observed which seemed ascribable to this, that or the other type of feeding—nor in view of the somewhat negative outcome of Larsen, Hungerford and Bailey's studies is it thought that the watering in any way affected the general outcome.

Despite the fact that digestion trials with sheep showed a considerably higher dry matter digestion coefficient from corn bran than from wheat bran, the latter yielded a 1 percent greater product which, of course, is within the limits of experimental error. *Mass. Sta. Bul. 186, pp. 142-153 (1918); Abstr. E. S. R. 41, pp. 276-277 (1919).*

Lindsey and Beal (1918) fed from 4 to 8 cows in seven trials, using the reversal system, the particular point in mind being to compare alfalfa hay with divers hays. When alfalfa was compared with a good mixed hay, production differences were well within the limit of experimental error. The digestible protein derived from alfalfa (78 percent of the total) was held to be as serviceable as a milk maker as that from the opposing ration, 58 percent of the protein of which was derived from beet pulp and gluten feed or meal. When compared wtih rowen hay and with "English" hay, yield differences were small.

The authors hold that alfalfa should not be used in the Eastern States as the sole source of roughage. *Mass. Sta. Bul. 186, pp. 105-141 (1918); Abstr. E. S. R. 41, pp. 275-276 (1919).*

Hayden (1918) fed 36 cows during four years by the reversal system in trials designed to compare clover and alfalfa hays. The latter ration made 10 percent more milk and 8 percent more fat but at the expense of 32 percent more protein and 8 percent more carbohydrates and fat. The nutrient consumptions per 100 pounds milk were: clover, 7.9 pounds digestible protein; 67.9 pounds digestible carbohydrates and fat (x 2¼); alfalfa, 9.5 and 67.2 pounds, respectively. The author deems a unit of clover protein superior as a milk maker to a unit of alfalfa protein. *Ohio Sta. Bul. 327 (1918); Abstr. E. S. R. 39, pp. 578-579 (1919).*

Woll and Voorhies (1919) further studied the value of alfalfa hay as a sole feed for milch cows, the general outcome being unfavorable as compared with that secured when other succulent feeds were added to the ration. *Cal. Sta. Rpt. (1919), pp. 72-76; Abstr. E. S. R. 42, p. 874 (1920).*

Larsen, Wright, Jones, Hoover and Johnson (1920) studied the relative values of feed protein for dairy cows, linseed meal and gluten feed being used for the purpose. These were primarily nitrogen balance trials. The percentage of availability of the feed nitrogen varied considerably, largely, it is thought, because of fluctuations in the energy intake. *So. Dak. Sta. Bul. 188 (1920); Abstr. E. S. R. 43, pp. 873-874.*

Morrison, Humphrey and Hulce (1920) fed 4 lots of 5 or 6 cows each by the reversal system in trials designed to compare barley and corn. The gains or losses by the partial replacement of one by the other were about 2 percent, being in one direction in one trial and the other in the other. *Wis. Sta. Bul. 319 (1920), p. 68; Abstr. E. S. R. 44, p. 271 (1921).*

### 8. ABSTRACTS SETTING FORTH THE VIEWS OF KELLNER, ARMSBY AND WOLL

What is the point of view of authorities in animal nutrition as expressed in their writings?

Kellner[1] (1910) cites rapid diminutions in milk flows and coincident falling off in body weight of cows with diminished intakes; points out the protective influence of plentiful supplies of carbohydrates in reducing food protein katabolism to such an extent that "all the digestible protein substance above that needed for maintenance can be utilized for the formation of milk without any call being made upon the protein of the body"; states that "for each 10 pounds of milk 0.55 to 0.65 pounds digestible protein in addition to that which the maintenance of the animal demands" should be supplied, which is equivalent to a 60 to 80 percent increase over the amount occurring in the milk; and discusses the point of view held 12 or more years ago as to the relation of non-proteins to milk production.

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[1] "Scientific Feeding of Animals," translated by Goodwin (Macmillan, N. Y.), pp. 325-329. (1910.)

Armsby, above every other American investigator of animal nutrition, is entitled to express an opinion. Discussing the "Production Values of Feeding Stuffs" in his volume, entitled "Nutrition of Farm Animals,"[1] he points out touching production values as regards protein, that the situation is not satisfactory; that the assumption held for many years that the different proteins of feeding stuffs possessed substantially equivalent nutritive values had been proven unwarranted; that proteins exist—for example, gelatin, zein (maize), gliadin (wheat)—which are ineffective in the support of body growth or in maintenance, being, as it were, "incomplete and unbalanced," lacking certain amino-acids which are characteristic of proteins in general and essential in nutrition. He states, however, that notwithstanding the general recognition of the validity of this newer point of view, its applicability in establishing net protein values is at present limited by a lack of adequate information as to the true nature of the protein contents of many roughages and concentrates; by a lack of information as to the requirements of farm animals for the different sorts of proteins, studies thus far made having dealt with total protein and not specific kinds; and by a lack of information as to the compensatory effects of surplusages of one sort of protein in the event of a deficiency of another sort. Recognizing the inadequacy of the present methods and pending their ultimate replacement by more exact experimentation, he holds that approximate production values are expressed by the digestible protein of the mixed ration. He cites the results secured at the Wisconsin and Missouri stations indicating the relatively low production values of the mixed proteins of maize, of wheat, and of alfalfa; and he discusses the newer point of view as to the value of "non-proteins," namely, that they may or may not possess production values according to the kind and proportion of their amino-acid contents, admitting at the same time the insufficiency of evidence warranting dogmatic statement or even generalization as to so heterogeneous a group. He inclines to the view that the digestible "true" protein, so-called, *i. e.*, the digestible crude protein less the digestible non-proteins, furnishes for the time being a safer basis of comparison than does the digestible crude protein, remarking that "a deficiency of protein (in a ration) may limit production while a surplus at worst simply tends to increase the cost."

At another point in the same volume,[2] under the heading "The utilization of protein in milk production," he defines the term as "the ratio of the protein contained in the milk to the least amount of feed protein which is required to produce it under the most favorable conditions." He declares that the amount secreted is determined in the main by the capacity of the individual; that an increased protein intake does not entail a materially increased protein outflow in the milk, the surplus being katabolized, thus involving a low apparent utilization factor; that a decidedly diminished protein intake tends to cause the mobilization, as it were, and utilization of tissue proteins as a source of milk protein, thus showing an overhigh and inaccurate apparent utilization factor; that, in short, "feed protein is substantially a supply of material and not a cause of production"; and that to determine the actual utilization of feed protein, its intake must be so reduced as to maintain the protein body status without loss or gain, a sufficiency of energy being supplied, and then compared with milk protein output. Citing the results of nitrogen balance work done at the New York (Geneva) and Pennsylvania stations, in Denmark and in Germany, he remarks that they "seem to indicate * * * that on low protein rations the protein of at least some feeding stuffs may be converted into milk protein without any very large loss."

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[1] Nutrition of Farm Animals (MacMillan, N. Y.), pp. 678-688 (1917).
[2] Ibid, pp. 488-493.

In yet another place in the same volume,[1] discussing protein requirements for milk production," he says concerning "minimum protein requirements," that if a 1,000-pound cow produces 25 pounds of 3.2 percent (protein) milk she needs must eat 1.4 pounds of digestible protein, 0.8 pounds for milk and approximately 0.6 pound presumably required for body maintenance; and that a lessened supply will result in lower yields or the conversion of body protein into milk protein. If, however, the nature of the mixed proteins fed is such that their percentage utilization, *i. e.*, the proportion capable of conversion into milk protein, is only 80 percent—which may well be true in many instances—it would appear that 1 pound would be needed to supply the 0.8 pound used in milk production, making a total of 1.6 pounds.

He further discusses the alleged stimulating effect of protein on the milk glands, which is held to bring about a more active secretion of all milk solids, citing Jordan's and Morgan's studies, the latter of which he considers to furnish "conclusive evidence of a stimulating effect of protein on milk production," notwithstanding the fact that in many instances carefully planned and rigidly controlled experimentation has shown no such outcome; which is but another way of saying that there are blanks as well as prizes in the protein-stimulus game. And he points out that in practical feeding trials in which the protein content of a ration has been markedly changed, "capricious results" have been secured, "showing no consistent relation between the excess of protein supplied and the relative increase of milk production secured."

Summarizing his review of this subject, he states:

"1. That no one figure can express the protein requirement for milk production * * * that it must vary with the amount and character of the milk produced.

"2. That a moderate rate of milk production may be maintained for a time on rations furnishing a comparatively small surplus of digestible protein over the milk protein plus the requirement for maintenance which experimental inquiry at the Wisconsin and Minnesota stations seems to place in commercial milk making, at 150 to 160 percent of the milk protein plus maintenance requirement.

"3. Some slight stimulating influence of excess protein on milk production is indicated but 'no basis (is available) for any estimate of the

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[1] Ibid, pp. 501-511.

**extent to which (it) will be economically profitable. * * * When circumstances warrant the effort to secure the maximum production possible, a more liberal supply of protein (may be) advantageous."**

**Reasoning by analogy is most dangerous, yet the writer in closing this chapter of the bulletin cannot refrain from referring to the following statements:**

**(1) "The minimal proteid requirement of the healthy man * * * is far below the generally accepted dietary standards. * * * The amount of proteid * * * needed daily for the actual physiological wants of the body is not more than one-half that ordinarily consumed by the average man."** ***Chittenden R. H., "Physiological Economy in Nutrition" (New York, F. A. Stokes Co.), p. 475 (1905.) (Studies on 14 people for 6-9 months on a low protein diet.)***

In what general direction do these multitudinous trials seem to point? It might be possible to summarize, to correlate their findings, but the writer can not attempt the task at this time. However, a somewhat careful critical general survey leads him to believe that while they point in several directions, the more carefully planned, better executed trials tend to confirm the results secured in these long time Vermont experiments. The writer is quite inclined to adopt as the final word in this bulletin a quotation from a publication of a sister station, penned by a past-master in animal nutrition.

Woll[1] states the case well—and he is well entitled to state the case in view of his prolonged experience in the dairy feeding world—when he says: "The general trend of the results of feeding experiments is in the direction of showing that protein feeds possess a somewhat higher value for milk production than feeding stuffs of a more carbonaceous character, but the profitable extent of feeding such feeds must be determined largely by local conditions. With a fair amount of protein in the ration supplied of farm-grown foods, the narrowing of the ration fed, by an addition of protein foods, is not a matter of prime importance. The testimony furnished by studies of the feeding practices conducted under a variety of conditions plainly shows that excellent results may be obtained by the use of quite wide ratios; a liberal supply of digestible matter in the rations of cows that are good producers is of importance, irrespective of the proportion of nitrogenous nutrients found there, if the rations contain a minimum of protein, which may be placed for different cows at from 1.3 to 1.5 pounds. At the same time it should be borne in mind that the cows are most likely to produce milk of the best quality of which they are capable, on rations that contain a fair amount of protein, and have nutritive ratios not wider than about 1:7, for cows in full flow of milk; under ordinary condition in the north central states a somewhat narrower nutritive ratio than this will, generally speaking, prove profitable, where the permanent effect on the production of the herd is kept in view."

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[1] **Wis. Sta. Bul. 116, p. 74 (1904). Abstr. E. S. R. 16, p. 911 (1905).**

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JUNE, 1922 BULLETIN 226

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# THE MAINTENANCE REQUIREMENTS OF DAIRY CATTLE

*By* J. L. HILLS

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# BULLETIN 226: THE MAINTENANCE REQUIREMENTS OF DAIRY CATTLE

By J. L. Hills[1]

NOTE.—The trials reviewed in this bulletin were started in 1907 at the instance of and under the general direction of Professor C. L. Beach, now President of the Connecticut Agricultural College, then dairy husbandman at this Station. From 1908 to 1911 they were guided by his successor, Professor R. M. Washburn, now of Minnesota; from 1911 to 1915 by Professor A. A. Borland, now of the Pennsylvania State College; from 1915 to 1918 by Professor G. F. E. Story, now Worcester (Mass.) County Agent; and from 1918 to their close by Professor H. B. Ellenberger. Their general conduct was incidental in a way to that of the extended protein trials discussed in bulletin 225. Messrs. W. J. Lamplough and E. R. Baker, computers, were responsible for a large part of the primal computations. And, during many long years, until he withdrew broken in health, day in and day out Mr. C. J. Cosgrove, barn foreman, attended to the multitudinous details of barn operation.

The final computations, comparisons and manuscript preparation, involving many months of consecutive attention, are the product of the writer, who acknowledges his deep indebtedness to his associates for their general guidance of the trials during their progress. In a very real sense they should be considered co-authors. He is especially grateful for the careful scrutiny of the galley proofs and many very helpful suggestions touching the same made by President Beach and Professors Borland and Ellenberger.

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[1] With the assistance and close cooperation of C. L. Beach, 1907-1908; R. M. Washburn, 1908-1911; A. A. Borland, 1911-1915; G. F. E. Story, 1915-1918; H. B. Ellenberger, 1918-1920. (See note.)

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# INTRODUCTION

The series of studies dealing with the maintenance[1] of dairy cattle discussed in this bulletin was inaugurated in the summer of 1907. It was expected that it would last approximately five years, but as a matter of fact it was not closed until late in 1920. Six cows were chosen at the outset and it was intended to limit the work to this number, but all told no less than 20 different cows were used. Furthermore, 61 other cows used in the protein trials (bulletin 225) contribute 324 records. The extreme refinements of animal experimentation have never been available nor was their use contemplated at any time. It is felt, however, owing to the long period devoted to the study, the large number of cows used and the considerable volume of the work, that the results obtained are worthy of credence.

When the trials were inaugurated the amount of data available in connection with the maintenance needs of dairy cattle was comparatively small. It was far from clear how much food a cow needed to keep herself alive, how much digestible protein and digestible carbohydrates and fat, how many calories of energy were thus employed. Furthermore, it was not clearly understood how much was needed by a dry farrow cow, by a dry pregnant cow, by a non-pregnant cow in full flush of milk, by a pregnant cow in milk; how much food was used in milk making, in the construction of the fœtus, in the maintenance of the animal body. It is obvious that these were pertinent questions in connection with dairy operations and that a serious attempt to solve them was worth while. However, during the 14 years since these trials were inaugurated, several studies of this important matter have been begun, finished and reported upon and much pertinent data have been accumulated, to which the present article adds only another chapter. Hence as a matter of fact this bulletin in large measure represents a critical review of the findings of the several investigators who have formulated standards for bovine maintenance and milk-making, the results secured in these long continued and comprehensive trials, longer continued and more comprehensive than any heretofore published, so far as the writer is aware, being used in attempting to determine the validity of their several dicta.

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[1] The word "maintenance" is used in this bulletin in two senses; in the restricted sense, referring to the sustenance of the live weight apart from the special milk-making function, and in the broader sense to cover the support of all bodily needs, including the specialized maternal functions. It is not thought that this will result in confusion or misunderstanding. There seemed to be no ready way of avoiding this dual usage of the term.

## SCOPE OF THE WORK

As a result of the 14 years of work, data have been secured along eight different lines, namely:

I. The maintenance of dry farrow cows for a period of less than 12 months (3 individual cows—3 records). Pages 32-33.

II. The maintenance of dry farrow cows for a period of more than 12 months (20 individual cows—20 records). Pages 34-55.

III. The maintenance of dry pregnant cows which calved normally (6 individual cows—7 records). Pages 55-65.

IV. The maintenance of dry pregnant cows which, later, aborted (5 individual cows—6 records). Pages 65-73.

V. The maintenance for a period of less than 12 months of non-pregnant milking cows following normal calving, including some which were in milk when served and some which were dried off when served (9 individual cows—16 records). Pages 74-92.

VI. The maintenance for a period of more than 12 months of non-pregnant milking cows following normal calving (13 individual cows—16 records). Pages 93-111.

VII. The maintenance of non-pregnant milking cows which had aborted (5 individual cows—5 records). Pages 111-120.

VIII. The maintenance of pregnant milking cows which calved normally (6 individual cows—11 records). Pages 120-139.

IX. To the data presented in sections V-VIII, inclusive are added those furnished by the records of several cows used in the protein trials which are published in bulletin 225, making a vast amount of material pertinent in the study of the maintenance needs of milking cows. Sixty-one individual animals contribute 324 records to this phase of the study. On account of the volume of the material and the fact that the records of these cows, had they been originally enlisted in the maintenance work, would have been listed in part in section V and in part in section VIII (the records of all aborters were excluded and the longest record was 224 days long, hence there were no records properly included in sections VI or VII) the material is grouped by itself under this special heading (61 individual cows—324 records). Pages 139-181.

It will be observed that data were obtained along four lines, namely: Maintenance *per se* (I, II); maintenance and fœtal construction (III, IV); maintenance and lactation (V, VI, VII and IX); maintenance, lactation and fœtal construction (VIII and IX).

## CONDUCT OF THE TRIALS[1]

### FEEDING

The food fed each cow was weighed daily and all rejected material weighed back and credited. The cows were weighed on three successive days each week throughout the trials. All water used was weighed daily. The temperatures of the barn in which they were housed was taken twice daily. They were never turned out to pasture but always kept either in the barn or in the exercise yard.[2]

The cows were fed hay daily, which varied more or less from year to year, containing in some years a larger proportion of clover than others; were fed silage for the larger part of the year; were fed apple pomace each fall; and, sometimes, soiling crops were fed during the summer. Three grain rations were used, namely, the so-called low, medium and high protein rations of the protein trials. These were made up by weight as follows:

*Low protein.* Wheat bran, 3; ground oats, 2; hominy feed 2.

*Medium protein.* Wheat bran, 3; ground oats, 1¾, gluten feed, 1; cottonseed meal, 1¼.

*High protein.* Wheat bran, 2; ground oats, 1; cottonseed meal, 2; old process linseed meal, 2.

Constant analytical check was maintained upon food intakes by weekly analyses of all fodders and feeds for dry matter and at least semi-annual complete fodder analyses, as is set forth at length in bulletin 225, dealing with the protein requirements of dairy cows. Milk analyses were made throughout the course of the trials, each week for total solid and fat contents, every five weeks for proteins, milk sugar and ash.

The average compositions of the three grain rations were as follows:

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[1] The conduct of the trials was in most respects identical with that obtaining in connection with the long continued protein trials, which is described in much detail on pages 12-51 of bulletin 225.

[2] Through error, or following abortion, a few cows were pastured for a few weeks each, as noted at appropriate places in the text.

| | Chemical composition | | | | | | | Digestible nutrients | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract | Dry matter | Crude ash | Crude protein | Crude fiber | Nitrogen-free-extract | Ether extract |
| | % | % | % | % | % | % | % | % | % | % | % | % | % |
| Low protein | 11.56 | 88.44 | 4.60 | 13.20 | 7.72 | 57.80 | 5.12 | 63.41 | 1.31 | 9.76 | 2.35 | 44.85 | 3.94 |
| Medium protein | 11.02 | 88.98 | 5.27 | 19.87 | 8.95 | 49.96 | 4.93 | 64.01 | 1.45 | 15.77 | 3.59 | 37.87 | 3.75 |
| High protein | 10.57 | 89.43 | 5.73 | 26.47 | 8.91 | 42.37 | 5.95 | 66.17 | 1.45 | 21.87 | 3.66 | 32.03 | 4.88 |

Full details as to the variations from these averages from time to time during the long experiment are to be found in bulletin 225.

Whenever a cow was fed a definite grain ration, the medium protein one, for example, she was continued upon that ration day in and day out, year in and year out, as long as she was used in these trials, whether for one year or for ten years, the grain ration never varying in respect to its composition, but of course varying in respect to the quantity fed, in accordance with what were deemed to be the needs of the cow or the exigencies of the trial.

The computations as to the nutrients eaten were made at two- and three-week intervals throughout the course of the trials; that is to say, a computation was made for a two-week interval, then for a three-, then for a two-, then for a three-, etc., thus enabling one at all times to keep a close check upon the work.

## THE COWS

In the summer of 1907, three grade Holsteins and three grade Jerseys were chosen and started upon their course. These animals had just calved normally and were listed at the outset in the study of nutrient usage in milk making and body maintenance. The low protein ration was fed to a grade Holstein and to a grade Jersey, the medium ration to another similar pair, and the high protein ration to a third. The grade Holstein fed the low protein ration, having completed her lactation, being then due to enter upon the period of maintenance, was found, as a matter of fact, to be in calf and was withdrawn, another grade Holstein being substituted. The tabular statement on pages 13-14 indicates the life histories of these cows while they were used in the maintenance trials, in so far as they relate to the times of the opening and closing of the several experimental periods.

At various times between the fall of 1912 and the spring of 1913, another lot of six cows, including two registered Ayrshires, one grade Holstein and three grade Jerseys, were started upon a course similar to that of their predecessors. They likewise were fed two the low, two the medium and two the high protein rations. Their life histories also are set forth in the tabular statement on pages 13-14.

During the winter and spring of 1914-15, five more cows, all grade Jerseys, were started upon similar work, their life histories appearing in the same tabular statement on pages 13-14.

And, finally, three cows, one registered Ayrshire and two grade Jerseys, were kept dry and unserved for a series of years—in one case over seven years—and were used in what colloquially was termed the "plunging" experiment, in that they were kept for a year as nearly as might be at an even food usage and weight and then for a year were fed sometimes scantily and sometimes abundantly, so that they lost and gained and lost and gained and lost and gained again; then for a year were maintained at a definite weight; and then again allowed to lose and gain back and forth. Their life histories also are indicated in the the tabular statement on pages 13-14.

The following conspectus sets forth a concise view of the plan of the trials, the cows used in each trial, I-VIII inclusive, and the period when in use in a given trial. Thus, for example, in the horizontal column—"Altje," the letter "i," listed under the heading "maintenance less than one year" in the upper lefthand corner of the table, indicates that this particular cow during the ninth period ("i" is the ninth letter of the alphabet) of her longdrawn out experimental usage was employed for a period of less than one year for the purpose of securing data touching maintenance *per se* and apart from considerations of milk making or fœtal construction. It will be noted that Altje, for example, contributed data in seven of the eight sorts of comparisons and in three instances, twice, whereas some cows, Vinegar, for example, only contributed twice, while three cows made each only a single contribution to the trials. This tabulation, taken in conjunction with the more detailed statement on pages 13-14, serves to show how, when and where the 20 cows were used.

DISTRIBUTION OF COWS AMONG THE SUNDRY TRIALS

| Name | Breed | Maintenance, less than one year | Maintenance, more than one year | Maintenance and foetus (normal calving) | Maintenance and fœtus (abortion) | Maintenance and milk, less than one year | Maintenance and milk, more than one year | Maintenance and milk, following abortion | Maintenance, milk and fœtus (less than one year) |
|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII |
| Altje | Gd. Holstein | i | b | .. | c, k | f | a, h | d | e, g |
| Bontje | Gd. Holstein | .. | d | e | .. | a, h | c, f | .. | b, g, i |
| Durtje | Gd. Holstein | .. | b | c | .. | d | a | .. | e |
| Hazel K | Gd. Jersey | .. | b | c | .. | a, d, f | h | .. | e, g |
| Jane | Gd. Jersey | .. | b | c | .. | a, d | .. | .. | e |
| Sabra | Gd. Jersey | .. | b | .. | c | a, f | h | d | e, g |
| Dell R | Gd. Ayrshire | .. | b | .. | .. | .. | a | .. | .. |
| Effa | Gd. Jersey | .. | b | .. | .. | .. | a | .. | .. |
| Evelyn | Gd. Holstein | .. | b | .. | .. | a | .. | .. | .. |
| Lanta 2nd | Reg. Ayrshire | .. | b | .. | .. | a | .. | .. | .. |
| Mary | Gd. Jersey | .. | b | .. | .. | .. | a | .. | .. |
| Nesbit | Gd. Jersey | e | b | f, h | c | a, g, i | .. | d | .. |
| Augusta | Gd. Jersey | .. | b | .. | c | .. | a | d | .. |
| Fizzy | Gd. Jersey | .. | b | .. | .. | .. | a | .. | .. |
| Isadore | Gd. Jersey | .. | b | .. | c, e | .. | a | d, f | .. |
| Karah | Gd. Jersey | e | b | c | .. | .. | a, d | .. | .. |
| Vinegar | Gd. Jersey | .. | b | .. | .. | .. | a | .. | .. |
| Hepsy | Gd. Jersey | .. | a | .. | .. | .. | .. | .. | .. |
| Lanta | Reg. Ayrshire | .. | a | .. | .. | .. | .. | .. | .. |
| Mab | Gd. Jersey | .. | a | .. | .. | .. | .. | .. | .. |
| Totals | | 3 | 20 | 7 | 7 | 16 | 16 | 6 | 11 |

NOTE.—Roman numerals, e. g., IV, refer to the particular trial, e. g., maintenance and fœtus (abortion), as well as to the section of this bulletin. Small letters, e. g., (d), refer to the period as shown in the table on pages 13-14. Thus, for example, the letters a, h under VI in the Altje horizontal column indicate that Altje was used in periods A and H in the study of maintenance and milk making costs for more than one year. Reference to the tables on pages 13-14 will indicate the duration of the periods in question.

## LIMITATIONS OF THE TRIALS

In trials lasting for such a long series of years and in which so many cows were employed, of necessity difficulties were encountered. This particular set seemed to be fated in many ways.

1. The trials suffered by the frequent change of the expert in charge. During the 13 years, no less than five different dairy husbandmen came and went. The trials were started by Professor C. L. Beach—for the last 12 years President of the Connecticut Agricul-

tural College. They were continued under the charge of his successor, Professor R. M. Washburn, who left to return to Minnesota, his native State and his Alma Mater, after three years' incumbency of the chair of animal husbandry at this institution. He bequeathed the trials to his successor, Professor A. A. Borland, who conducted them for four years and then left to return to Pennsylvania, his native State and Alma Mater. He transmitted them in turn to Professor G. F. E. Story, who remained three years and returned from whence he came, to the employ of the Massachusetts Agricultural College. He passed them on to the present incumbent, Professor H. B. Ellenberger. Obviously, so many changes in oversight have injuriously affected the continuity of the work. Furthermore, these various men had multifarious duties other than the conduct of this particular trial, which in every instance constituted a relatively minor portion of their work; and on that account, likewise, it suffered.

2. For a long series of years, the barn foreman was one and the same individual. He was reasonably careful in his conduct of the work. During the last few years, however, the turn-over of farm help has been excessive. Many men have had charge of the barn work. Some of them were thoroughly incompetent and, notwithstanding such oversight as could be maintained under the conditions set forth in the preceding paragraph, did not do their work well. This situation is one which now has become a commonplace everywhere.

3. Abortion and sterility have greatly affected the continuity of the work. In an investigation of this character, the breaking of a single link in the chain seriously affects the usefulness of all the work.

4. To cap the climax, three record books, kept in the fireproof vault in Morrill Hall, disappeared during the fall of 1920. They contained the live weight records for three years, 1914-1917. Many hours of search in every direction failed to locate them. They were in the vault in early September, being referred to but not taken from the vault by one of the writer's associates. They were missed early in October. It seems highly probable that they were stolen, possibly by some student who coveted them as note books.

After mature deliberation it was thought best to try to arrive at approximations of the average weights in each instance. It was felt that this could be done with a reasonable assurance of approximate accuracy. Multitudinous weight records of all the cows were in hand, records made some before and some after the period in question, and in many instances both before and after. Furthermore, in several instances there were extant live weight records of the same cows made under similar conditions as to feeding, period of lactation, etc. With these data in hand, it was felt that attempts at approximation were warranted, and such were made, all the factors entering into the problems being given due weight. When the final figures in each case were secured, they were put to one side until all had been determined. Then all the data and all the circumstances were reviewed once again and independently of the former computations, and the results laid aside. And, finally, the same procedure was once more and again independently carried out. Then for the first time the three sets of figures were compared and were found in almost every case to be closely comparable. Whatever differences occurred, the reasoning and computation back of the divergent figures were scanned afresh. No attempt was made to fix upon a final figure closer than 10 pounds. In this fashion average hypothetical live weight data have been supplied in lieu of the missing figures. It seemed better to do this than to discard so large a proportion of the total work. Furthermore, the greater part of the damage was located in section II (maintenance for long periods of time in excess of 12 months). It affects 24 of the 83 records used in this bulletin.

Unfortunately this unhappy loss—which can hardly have been anything but theft—quite wrecked one portion of the trial wherein it was intended to measure maintenance, live weight losses and live weight gains alternately over long periods of time. Thus one cow, Lanta, a registered Ayrshire, was fed while dry and barren for more than seven years with a view of studying this matter, and her record is quite useless except as a unit. Whenever the record as used in any of sections I to IX, inclusive, is thus faulty, specific attention is called to the fact.

It should not be forgotten, when noting the faults underlying this trial, that because of the great volume of the work, the considerable number of the animals employed, and the extreme length of the experiment, these limitations to the contrary notwithstanding, the ultimate outcome is one in which one can justly feel a considerable degree of confidence. The generous scope of the work may be better appreciated if one understands that 35,851 cow-days, or more than 98 years of cow life, were involved; that, in other words, the 20 cows used were kept busy in this trial on the average of nearly five years apiece. Furthermore, the 324 records derived from the protein trials in bulletin 225 covered 47,477 more cow-days, or 130 years of cow-life. The total figures are 83,328 days and 228+ years.

THE COWS AND THEIR USAGE IN THE SEVERAL TRIALS

| Name | Breed | Protein ration | Initial age years | Section and number | Period A From | to | Section and number | Period B From | to | Section and number | Period C From | to |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Altje | Gd. Holstein | Med. | 6 | VI 1 | C 7- 6-07—D | 12-10-08 | II 1 | D 12-10-08—S | 1-10-10 | IV 1 | S 1-10-10—A | 8- 2-10 |
| Bontje | Gd. Holstein | Low | 5 | V 2 | C 10-24-07—S | 3-26-08 | (1) | S 3-26-08—C | 12-27-08 | VI 3 | C 12-27-08—D | 3-24-10 |
| Durtje | Gd. Holstein | High | 5 | VI 5 | C 7- 5-07—D | 12- 3-08 | II 3 | D 12- 3-08—S | 1-15-10 | III 2 | S 1-15-10—C | 10-20-10 |
| Hazel K | Gd. Jersey | Low | 4 | V 5 | C 8-22-07—D | 7-14-08 | II 4 | D 7-14-08—S | 11-28-09 | III 3 | S 11-28-09—C | 8-31-10 |
| Jane | Gd. Jersey | High | 4 | V 8 | C 8- 7-07—D | 7- 9-08 | II 5 | D 7- 9-08—S | 9- 7-09 | III 4 | S 9- 7-09—C | 6-15-10 |
| Sabra | Gd. Jersey | Med. | 5 | V 10 | C 8-14-07—D | 7-12-08 | II 6 | D 7-12-08—S | 9-13-09 | IV 3 | S 9-13-09—A | 5-25-10 |
| Dell R | Gd. Jersey | High | 4 | VI 7 | C 5- 3-13—D | 9- 5-14 | II 7 | D 9- 5-14—off | 8- 3-17 | discarded | | |
| Effa | Gd. Jersey | Low | 5 | VI 8 | C 6- 4-13—D | 10-15-14 | II 8 | D 10-15-14—off | 7-12-17 | discarded | | |
| Evelyn | Gd. Holstein | Low | 5 | V 12 | C 9-29-12—D | 5- 2-13 | II 9 | D 5- 2-13—off | 5- 3-17 | sold 5-10-17 | | |
| Lanta 2nd | Reg. Ayrshire | Med. | 4 | V 13 | C 8-20-12—D | 7- 3-13 | II 10 | D 7- 3-13—off | 6-28-17 | sold 7-23-17 | | |
| Mary | Gd. Jersey | Med. | 4 | VI 9 | C 5-16-12—D | 8-20-14 | II 11 | D 8-20-14—off | 7-19-17 | sold 7-23-17 | | |
| Nesbit | Gd. Jersey | High | 5 | V 14 | C 12-22-12—D | 10- 2-13 | II 12 | D 10- 2-13—S | 9-21-15 | IV 4 | S 9-21-15—A | 6-11-16 |
| Augusta | Gd. Jersey | High | 4 | VI 11 | C 5- 8-15—D | 7- 6-16 | II 13 | D 7- 6-16—S | 1-27-19 | IV 6 | S 1-27-19—A | 9-13-19 |
| Fizzy | Gd. Jersey | High | 2 | VI 12 | C 11- 4-14—D | 5- 4-16 | II 14 | D 5- 4-16—off | 8-15-18 | died | | |
| Isadore | Gd. Jersey | Med. | 8 | VI 13 | C 6- 3-15—D | 7-20-16 | II 15 | D 7-20-16—S | 1-16-18 | IV 5 | S 1-16-18—A | 7- 5-18 |
| Karah | Gd. Jersey | Low | 5 | VI 15 | C 1-15-15—D | 5-25-16 | II 16 | D 5-25-16—S | 8- 4-18 | III 5 | S 8- 4-18—C | 5-16-19 |
| Vinegar | Gd. Jersey | Med. | 4 | VI 14 | C 4- 1-15—D | 6- 8-16 | II 17 | D 6- 8-16—off | 12-20-17 | | | |
| Hepsey | Gd. Jersey | High | 9 | II 18 | on 1- 7-16—off | 6-28-17 | sold 8-2-17 | | | | | |
| Lanta | Reg. Ayrshire | Low | 7 | II 19 | on 11- 5-09—off | 3-29-17 | killed | | | | | |
| Mab | Gd. Jersey | Low | 8 | II 20 | on 1- 7-16—off | 6-28-17 | sold 7-24-17 | | | | | |

| Name | Breed | Protein ration | | | Period D From | to | | Period E From | to | |
|---|---|---|---|---|---|---|---|---|---|---|
| Altje | Gd. Holstein | Med. | | VII 2 | A 8- 2-10—S | 12-13-10 | VIII 1 | S 12-13-10—C | 9-17-11 | |
| Bontje | Gd. Holstein | Low | | II 2 | D 3-24-10—S | 7- 5-11 | III 1 | S 7-15-11—C | 4-15-12 | |
| Durtje | Gd. Holstein | High | | V 4 | C 10-20-10—S | 6- 9-11 | VIII 5 | S 6- 9-11—C | 3-16-12 | sold 4-30-12 (lost 2 quarters) |
| Hazel K | Gd. Jersey | Low | | V 6 | C 8-31-10—S | 3- 8-11 | VIII 6 | S 3- 8-11—C | 12-15-11 | |
| Jane | Gd. Jersey | High | | V 9 | C 6-15-10—S | 12- 5-10 | VIII 8 | S 12- 5-10—C | 9-13-11 | killed 3-6-12 (wire) |
| Sabra | Gd. Jersey | Med. | | VII 2 | A 5-25-10—S | 10-11-10 | VIII 9 | S 10-11-10—C | 7-14-11 | |
| Nesbit | Gd. Jersey | High | | VII 3 | A 6-11-16—D | 1- 4-17 | I 2 | D 1- 4-17—S | 6-27-17 | |
| Augusta | Gd. Jersey | High | | VII 4 | A 9-13-19—off | 2- 6-20 | sold in milk | | | |
| Isadore | Gd. Jersey | Med. | | VII 5 | A 7- 5-18—S | 6-12-19 | IV 7 | S 6-12-19—A | 2-13-20 | |
| Karah | Gd. Jersey | Low | | VI 10 | C 5-16-19—D | 6-24-20 | I 3 | D 6-24-20—S | 10- 3-20 | |

THE COWS AND THEIR USAGE IN THE SEVERAL TRIALS—*concluded*

| Name | Breed | Protein ration | Section and number | Period F |  | Section and number | Period G |  | Section and number | Period H |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | From | to |  | From | to |  | From | to |
| Altje | Gd. Holstein | Med. | V 1 | C 9-17-11—S | 12- 4-11 | VIII 2 | S 12- 4-11—C | 9- 7-12 | VI 2 | C 9- 7-12—D | 2- 5-14 |
| Bontje | Gd. Holstein | Low | VI 4 | C 4-15-12—S | 8-26-13 | VIII 3 | S 8-26-13—C | 6- 5-14 | V 3 | C 6- 5-14—S | 9-15-14 |
| Hazel K | Gd. Jersey | Low | V 7 | C 12-15-11—S | 2- 9-12 | VIII 7 | S 2- 9-12—C | 11- 9-12 | (1) | C 11- 9-12—D | 5- 6-14 |
| Sabra | Gd. Jersey | Med. | V 11 | C 7-14-11—S | 12-26-11 | VIII 10 | S 12-26-11—C | 9-29-12 | VI 6 | C 9-29-12—off | 10-15-13 |
| Nesbit | Gd. Jersey | High | III 6 | S 6-27-17—C | 4-10-18 | V 15 | C 4-10-18—S | 9-24-18 | III 7 | S 9-24-18—C | 7- 2-19 |
| Isadore | Gd. Jersey | Med. | VII 6 | A 2-13-20—D | 10-19-20 |  |  |  |  |  |  |

| Name | Breed | Protein ration | Section and number | Period I |  | Section and number | Period K |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | From | to |  | From | to |  |
| Altje | Gd. Holstein | Med. | I 1 | D 2- 5-14—S | 5- 9-14 | IV 2 | S 5- 9-14—A | 12- 1-14 | killed 3-12-15 (wire) |
| Bontje | Gd. Holstein | Low | VIII 4 | S 9-15-14—C | 6-22-15 | discarded, udder impaired |  |  |  |
| Hazel K | Gd. Jersey | Low | sold, barren |  |  |  |  |  |  |
| Sabra | Gd. Jersey | Med. | sold in milk |  |  |  |  |  |  |
| Nesbit | Gd. Jersey | High | V 16 | C 7- 2-16—D | 6-29-20 |  |  |  |  |

NOTE.—"*Section and number*" refers to the location in the trials. For instance, Altje VI 1 indicates that the cow in question was used from calving (C) July 7, 1907, until she dried off (D) December 10, 1908, in the trials scheduled under Section VI and that her record is the first (1) discussed in that section.

The various letters mean: C, calved; D, dried off; S, served; A, aborted.

(1) Bontje (Period B) and Hazel K (Period H) were pastured through misunderstanding.

## CONCERNING FEEDING STANDARDS

Several dicta have been put forth by different investigators touching the maintenance needs of the various kinds of domestic animals. The first feeding standard wherein animal needs were specifically set forth in terms of amounts of total nutrients was published in Germany in 1858 by Grouven. Six years later Wolff formulated his standards based on the digestible nutrient contents of the ration, which became thoroughly fixed by 1874. These were the so-called German feeding standards introduced in this country in the mid-seventies by Johnson, Atwater and others. Lehmann (1899) added to and modified these Wolff formulas in several ways, especially in respect to that for milch cows. Kühn (1897), Maercker (1902), Hansson (1902), Kellner (1905-06) and others in Europe have suggested standards. Several students of animal nutrition in America have set forth their ideas touching this matter. During the nineties Atwater and Phelps (1894, 1897), Woll (1894) and Smith (1897) suggested standards for dairy cattle; and, during more recent years, as a result of much more careful, fundamental and prolonged investigation, Woll and Humphrey (1910), Haecker (1904, 1912, 1914), Savage (1912), Eckles (1913) and Armsby (1916) have suggested sundry standards, more especially for the dairy cow; whereas Morrison (1917) and McCandish (1920) have suggested certain modifications of the Haecker and Savage statements.

The following tabulations (I-IV) set forth such statements of this character (omitting certain earlier and relatively inadequate statements) as have come to the writer's attention in so far as they refer to bovines. It well may be that some standards have been proposed which have escaped his notice. They are not uniformly expressed, being variously indicated according to the notions of their proponents and the advance in knowledge and in investigational methods. The order of statement is in a general way chronological.

### I. MAINTENANCE STANDARDS

| | Total dry matter | Digestible crude protein | Digestible carbohydrates | Digestible fat | Total digestible nutrients | Nutritive ratio (1), starch value (2), therms (3), food units (4) | Authority | Citation |
|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | | | |
| Ox at rest..... (1,000 lbs.) | 18. | 0.7 | 8. | 0.1 | ...... | 1.: 11.8 (1) | Wolff-Lehmann | Mentz v. Leng Kal. |
| | 13.-21 | 0.6-0.8 | .. | .. | 8.4-10.4 | 1.: 10. to 16 (1) | Wolff-Lehmann (mod. by Morrison) | Henry's Feeds and Feeding |
| | ..... | 0.7 | 6.6 | .. | ...... | ............... | Kühn | Land V. S. 44 |
| | 15.-21. | 0.6-0.8 | .. | .. | ...... | 6. (2) | Kellner | † |
| | ..... | 0.4-0.6 | .. | .. | ...... | ............... | Armsby | U.S.D.A. |
| (750 lbs.) | 20. | 0.4* | .. | .. | ...... | 4.95 (3) | Armsby | Bul. |
| (1,000 lbs.) | ..... | 0.5* | .. | .. | ...... | 6. (3) | Armsby | 346 |
| (1,250 lbs.) | —35. | 0.6* | .. | .. | ...... | 7. (3) | Armsby | (1909) |
| Barren cow.... (1,000 lbs.) | ..... | 0.6 | 7. | 0.1 | ...... | ............... | Haecker | Minn. Bul. 79 |
| Milking cow .. (1,000 lbs.) | ..... | 0.7 | 7. | 0.1 | ... .. | ............... | Haecker | Minn. Bul. 79 |
| Cow .......... | ..... | 0.65 | .. | .. | ...... | 6.6 (4) | Hanssen | ‡ |
| (1,000 lbs.) | 12.5 | 0.7 | .. | .. | 7.9 | ............... | Woll-Humphrey | Wisc. R. Bul. 13 |
| | ..... | 0.7 | .. | .. | 7.925 | ............... | Savage | Cornell Bul. 322 |
| | ..... | 0.7 | .. | .. | 7.925 | .............. | Wolff-Lehmann (mod. by Morrison) | Henry's Feeds and Feeding |
| | ..... | 0.5* | .. | .. | ...... | 6. (3) | Eckles | Mo. Rsch. Bul. 7 |

*Digestible *true* protein. †Ernäh. d. landw. Nutz. (1905). ‡Kontr. Arbets. (1910).

There seems to be a reasonably substantial agreement in respect to the maintenance needs of the cow. The several maintenance statements, reduced as nearly as may be to equivalent terms, range on the 1,000 pound live weight basis from 0.6 to 0.7 pounds digestible crude protein and 7.83 to 7.93 pounds of total digestible nutrients (4 standards) and 6 therms (2 standards). When, however, it comes to the statement of the food requirements in milk making, greater variation occurs.

The next three tables set forth the statements made by the parties indicated touching the food needs of the milking cow.

### II. STANDARDS FOR MILK-MAKING

| For each pound of milk of given fat percentage | Modified Wolff-Lehmann | | Haecker (1914 form) | | Savage | | Eckles | | Armsby | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients | Digestible true protein | Net energy | Digestible true protein | Net energy |
| | lbs. lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | therms | lbs. | therms |
| **For maintenance 1,000 lb. cow**............ | 0.700 | 7.925 | 0.700 | 7.925 | 0.700 | 7.925 | 0.500 | 6.00 | 0.500 | 6.00 |
| 2½ ................ | 0.045-0.053 | 0.256 | 0.045 | 0.254 | 0.053 | 0.257 | .... | ... | 0.041 | 0.19 |
| 3 ................ | 0.047-0.057 | 0.286 | 0.047 | 0.284 | 0.057 | 0.287 | 0.05 | 0.26 | 0.043 | 0.214 |
| 3½ ................ | 0.049-0.061 | 0.316 | 0.049 | 0.313 | 0.061 | 0.319 | 0.052 | 0.28 | 0.045 | 0.238 |
| 4 ................ | 0.054-0.065 | 0.346 | 0.054 | 0.343 | 0.065 | 0.350 | 0.055 | 0.30 | 0.049 | 0.265 |
| 4½ ................ | 0.057-0.069 | 0.376 | 0.057 | 0.372 | 0.069 | 0.379 | 0.058 | 0.33 | 0.052 | 0.291 |
| 5 ................ | 0.060-0.073 | 0.402 | 0.060 | 0.398 | 0.073 | 0.405 | 0.062 | 0.36 | 0.055 | 0.315 |
| 5½ ................ | 0.064-0.077 | 0.428 | 0.064 | 0.424 | 0.077 | 0.431 | 0.066 | 0.40 | 0.058 | 0.338 |
| 6 ................ | 0.067-0.081 | 0.454 | 0.067 | 0.451 | 0.081 | 0.457 | 0.070 | 0.45 | 0.061 | 0.361 |
| 6½ ................ | 0.072-0.085 | 0.482 | 0.072 | 0.480 | 0.085 | 0.484 | 0.075 | 0.50 | 0.064 | 0.385 |
| 7 ................ | 0.074-0.089 | 0.505 | 0.074 | 0.502 | 0.089 | 0.508 | .... | ... | 0.068 | 0.408 |

### III. STANDARDS FOR MILK-MAKING (Cont.)

| Wolff-Lehmann 1,000-lb. cow | | | | Atwater & Phelps | | | | | | | Kellner 1,000-lb. cow | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 750-900-lb. cow | | | | 950-1,100-lb. cow | | | | | | |
| Milk | Digestible protein | Digestible carbohydrates | Digestible fat | Milk | Digestible protein | Digestible carbohydrates | Digestible fat | Digestible protein | Digestible carbohydrates | Digestible fat | Milk | Digestible protein | Digestible carbohydrates | Digestible fat |
| lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 11 | 1.6 | 10 | 0.3 | 10/20 | 2. | 11 | 0.4 | 2.3 | 13 | 0.5 | 10 | 1.4 | 10. | 0.3 |
| 16½ | 2 | 11 | 0.4 | 20/25 | 2.3 | 11 | 0.5 | 2.6 | 13 | 0.6 | 20 | 2.1 | 12.2 | 0.5 |
| 22 | 2.5 | 13 | 0.5 | 25/30 | 2.6 | 11 | 0.5 | 2.9 | 13 | 0.6 | 30 | 2.6 | 13.8 | 0.6 |
| 27½ | 3.3 | 13 | 0.8 | 30/35 | 2.9 | 12 | 0.6 | 3.2 | 14 | 0.7 | 40 | 3.6 | 14.6 | 0.8 |
| | | | | 35/40 | 3.2 | 12 | 0.6 | 3.5 | 14 | 0.7 | | | | |

NOTE: Dry matter omitted. Atwater and Phelps' digestible carbohydrates and fat figures are expressed as minima and maxima, i. e., 10-12. Average is given, i. e., 11. The "spread" is always two points, i. e., 10-12 or .3-.5. Kellner's digestible protein and carbohydrate figures are similarly expressed, the spreads being 0.4 (protein) and 0.4, 1.3, 1.8 and 1.4 (carbohydrates).

### IV. STANDARDS FOR MILK-MAKING (Cont.)[1]

Wolff: 24. lbs. organic matter, 2.5 lbs. digestible protein, 12.5 lbs. digestible carbohydrates, 0.4 lbs. digestible ether extract.

Woll: 23.41 lbs. organic matter, 2.15 lbs. digestible protein; 13.27 lbs. digestible carbohydrates; 0.74 lbs. digestible ether extract.

Atwater and Phelps: 25 lbs. organic matter, 2.5 lbs. digestible protein, 13 to 12 lbs. digestible carbohydrates, 0.5 to 0.8 lbs. digestible ether extract (earlier form).

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[1] Per 1,000-lb. cow.

**Smith:** 23.57 lbs. dry matter, 2.06 lbs. digestible protein, 12.5 lbs. digestible carbohydrates, 0.89 lbs. digestible ether extract.

**Hanssen:** To maintenance ration (0.65, 6.6) add per pound of milk 0.045-0.05 pounds digestible crude protein and 0.33 feed units. (See Vt. Sta. Bul. 158, pp. 200-203.)

**Armsby:** To maintenance ration (0.4-0.6, 4.95-7.) add per pound of 4. percent milk 0.05 pounds digestible true protein and 0.3 therms (earlier form).

**Woll-Humphrey:** To maintenance ration (0.7, 7.9) add: for less than ½ lb. fat 1.15 lbs. digestible crude protein, 10.6 lbs. total digestible nutrients; for ½ to ¾ lb 1.49 and 12.3; for ¾ to 1 lb., 1.8 and 14.1; for 1 to 1¼ lbs., 2.11 and 15.8; for 1¼ to 1½ lbs., 2.43 and 17.6; for 1½ to 1¾ lbs., 2.74 and 19.3; for 1¾ to 2 lbs., 3.05 and 21.1 lbs.

*Wolff's* original standard (IV) was a single statement and based on physiological considerations. It took no account of either the quantity or quality of the milk flow. *Lehmann* (III), revising this standard at a later period, varied it by taking account of the quantity differences in milk flows, without regard to quality variations.

*Woll's* statement, a single one (IV), was based on the average feeding practice of 128 Wisconsin farmers, some of which was good, some less good. This hardly, in the proper sense of the term, constitutes a standard.

*Atwater and Phelps* (III, IV) set up two different standards, the earlier form closely resembling the Wolff standard, the latter based upon the Wolff-Lehmann idea of varying nutrient usage for varying quantities of milk.

*Smith's* formula (IV) merely set forth what happened to be fed to a certain college herd during a certain winter; but it was termed "a standard."

*Hansson* (I, IV) built his standard upon an arbitrary basis of somewhat doubtful applicability in respect to American fodders and feeds, on the so-called "feed unit" basis, a feed unit representing a pound of a standard grain or its equivalent in fodders or feeds.

*Kellner* (I, III) struck out in a quite new path and, as a result of experimentation with a modern respiration apparatus, suggested feeding standards, varied for different milk yields, based in part upon net food values rather than digestible food values, deducting the energy expended in the work of mastication, digestion and assimilation from the available energy furnished by the total digestible nutrients. He set forth his standards in terms of what he called "starch values." With one pound of digestible starch as his unit, he considered a pound of digestible protein to have 0.94 pound, digestible carbohydrates one pound, and fats from 1.61 to 2.41 pounds starch value according to their origin. His standard for milch cows, however, was also expressed in terms of digestible crude protein, carbohydrates and fat.

*Woll and Humphrey* (I, IV) set forth a standard based upon the varying fat contents of milks, *i. e.*, 1 pound, 1½ pounds, 2 pounds. It took no cognizance, however, of the fact that a pound of fat, for example, may be contained in 33.3 pounds of 3 percent milk or in 16.7 pounds of 6 percent milk.

The *Haecker* standard for milk production (I, II) was the first in which the difference between milks were recognized and nutrient usages adjusted to such differences. For some years, however, it was a variable rather than a fixture. When first set forth in 1904 (Minn. Sta. Bul. 79, p. 104) it was very definite. However, it was justly criticized on the ground that it was predicated on meagre data. Consequently, in 1912, a second set of figures "as used in his classroom," was published (N. Y.—Cornell—Sta. Bul. 322, p. 77). This varied considerably from its predecessor, being higher on the average by about 2 percent in digestible protein and 7 percent in total digestible nutrients. Then, in 1913 and 1914, a third set of figures was announced (Minn. Sta. Buls. 130, pp. 12-14; 140, p. 56) entirely unlike either of the standards which had been issued earlier. This 1914 model averages 13 and 10 percents higher in respect to digestible protein and 16 and 8 percents higher in respect to total digestible nutrients than those which preceded it. Unfortunately, no reference is made in any of these later publications to the fact that the newly proposed figures supersede others. This has caused confusion; and so it happens that three different so-called Haecker standards have been in use at the same time. Indeed, the most recent American proposer of a standard, making use of one of Haecker's in the formulation of his own newly derived standard, fell into the error of employing one of the temporary forms. It is now seven years since the last change was made; furthermore, Professor Haecker has retired and is enjoying well-earned rest; hence it seems fair to assume that no further alteration is contemplated.

The following excerpts from these several standards illustrate the situation. The 1913 and 1914 forms are really identical—differing only in the matter of the last decimal.

O BE FED IN ADDITION TO MAINTENANCE STANDARD PER POUND OF MILK OF THE FAT CONTENT INDICATED

| | Digestible protein | | | | Digestible carbohydrates | | | | Digestible ether extract | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1904 | 1912 | 1913 | 1914 | 1904 | 1912 | 1913 | 1914 | 1904 | 1912 | 1913 | 1914 |
| percent | .0397 | .0420 | .047 | .0469 | .181 | .189 | .2 | .199 | .0136 | .0133 | .017 | .0170 |
| percent | .0467 | .0480 | .054 | .0539 | .214 | .233 | .24 | .242 | .0159 | .0164 | .021 | .0208 |
| percent | .0537 | .0540 | .060 | .0604 | .247 | .271 | .28 | .284 | .0182 | .0191 | .024 | .0243 |
| percent | .0607 | .0600 | .067 | .0668 | .280 | .307 | .32 | .322 | .0206 | .0216 | .028 | .0276 |
| percent | .0677 | .0660 | .... | .0738 | .313 | .341 | ... | .359 | .0229 | .0242 | .... | .0308 |

The *Savage* standard (I, II), like all which have been proposed during the last 15 years, recognizes that the amounts of nutrients suggested need to be varied according to the richness of the milk. It is based upon a considerable amount of experimentation carried out by the author as well as by others and represents his deductions from the material in hand.

*Armby* (I, II) first set forth his standard for milk in simple terms of the needs of 4 percent milk but, later, differentiated as between milk of various grades in his "Production Value Tables."

The *Eckles* standard (I, II) is modestly termed a "tentative statement." It strikes out in quite a new line in that it adopts the idea set forth by Kühn and Armsby that true protein rather than crude protein should be the basis of statement as to the needs for this nutrient. Eckles follows Armsby in discarding the total digestible nutrients, carbohydrates, fat, etc., form of statement and expressing energy needs in terms of therms. His dicta are based upon data derived from experimentation with 18 farrow cows fed a year apiece and two farrow cows fed three and one-half and fourth months apiece.

*Morrison's* so-called "modified Wolff-Lehmann's" standard (I, II) represents simply an average of the Haecker (1914 form) and Savage standards, expressed, so far as digestible protein is concerned, as minima and maxima, and, so far as total digestible nutrients are concerned, as averages. The writer can not but feel that to term these modified Wolff-Lehmann standards is a misnomer, since the figures represent neither Wolff's nor Lehmann's but Haecker's and Savage's; but so they are called and the accepted terminology is adopted here.

*McCandlish's* modification represents simple means, the Haecker (1912 form) and Savage digestible protein requirements being averaged. This average is subtracted from the average of the two total digestible nutrient statements and expressed as a "carbohydrate equivalent."

The multiplicity of standards set up by students of animal nutrition in this and other lands makes for confusion. There are 15 of them listed in these tables and not all are included. Furthermore, they differ among themselves as to method of statement and amounts of nutrients suggested for various grades of milk, as well as for the same grade of milk. Some are expressed in terms of digestible crude protein, some of digestible true protein; some in terms of total digestible nutrients, some in terms of therms of energy; some are based on milk weights, some on butter fat weights. They can not all be right. If one confines oneself only to the American standards of the past ten years, one has to deal with the dicta of Woll and Humphrey, of Haecker (the 1904, 1912 and 1914 forms), of Savage, of Morrison, (modified Wolff-Lehmann), of Eckles, of Armsby and of McCandlish, all of them differing more or less, some more, some less, among themselves. To tabulate the data for each cow and each period in the feeding trials lasting from 1906 to 1920 as shown in sections V. to VIII. of this bulletin, and to compare the results with the calculated results according to each of these many standards, would necessitate extremely complicated tables, which could not be placed upon a page, even if placed sidewise. Now the writer abominates tables printed sidewise of the page. Few people read tables anyhow; and very few even look at sidewise tables. However, comparisons could be made in tables printed upright, if only three—or, perhaps by crowding, four—standards were used for comparison. It seemed best under the circumstances to make no use of any of the European standards or the earlier suggestions made on this side of the water during the nineties; furthermore, to make no use of five of the more recently proposed American standards for the reasons indicated below; to use only three in full, namely the Haecker (1914 form), Savage and Eckles (converted), because of their wide acceptation, their representativeness and their unlikenesses; and to print the Armsby (converted) comparisons in the 46 main tables in sections V. to VIII. (pages 74 to 139), apart from the other three, so that tabular perpendicularity might be maintained. This procedure makes the interpretation of the tables somewhat obscure but the broad double line of separation used in each table should serve to clarify them.

The reasons which actuated the writer in not tabulating the data furnished by the use of five American standards may be stated succinctly as follows.

*Woll-Humphrey.* Use of fat weights instead of milk weights as a basis, being unlike all other standards in this respect; an illogical basis in that it does not take into account the varying contents of milk albuminoids in, for example, 20 lbs. of 5 percent and 40 lbs. of 2½ percent milk, each containing 1 pound of fat.

*Morrison* (so-called modified Wolff-Lehmann). Digestible protein figures expressed as minima and maxima, therefore indefinite; minima and maxima represent simply the Haecker (1914 form) and Savage figures, respectively; total digestible nutrient figures are simply the average of the Haecker (1914 form) and Savage figures. It is obvious that anyone who desires to know the results of comparisons with this standard actually has the figures before him in each instance.

*Haecker* (1904 and 1912 forms). Superseded by 1914 standard.

*McCandlish.* Simply the averaging of the Savage and a temporary (1912) form of the Haecker standard (which the author presumably has repudiated by the issuance of greatly increased figures in 1914); and the calculation of a "carbohydrate equivalent" from such averages.

Data are furnished in the sidelines of every one of the 46 tables in sections VI. to VII., which, in conjunction with the matter on pages 17 to 22, will enable anyone who desires quickly and accurately to calculate each individual comparison for any one or all of the several standards, this for both digestible crude protein and total digestible nutrients.

The Armsby and Eckles standards are stated in terms of digestible *true* protein and of *therms* of net energy instead of in terms of digestible crude protein and total digestible nutrients. Now the ratios of the one to the other vary in different fodders and feeds. Calculation from the data supplied by Armsby[1] for the more important American grown materials, furnishes the subjoined table.

DIGESTIBLE "CRUDE" AND "TRUE" PROTEINS; TOTAL DIGESTIBLE NUTRIENTS AND THERMS; RATIOS, RANGES AND AVERAGES

| | | Digestible crude protein | | Digestible true protein | | Ratios of digestible crude to true protein | |
|---|---|---|---|---|---|---|---|
| | | Range | Ave. | Range | Ave. | Range | Ave. |
| | | % % | % | % % | % | 100: | 100: |
| Grains and seeds..... | 13 | 6.1-30.7 | 13. | 5.7-27.3 | 11.6 | 87-93 | 90 |
| By-products* ......... | 11 | 7. -37. | 22.4 | 6.3-35.4 | 20.8 | 82-97 | 92 |
| By-products† ......... | 4 | 1. -20.3 | 6.8 | 0 -12.5 | 3.3 | 0-62 | .. |
| Hay and dry coarse fodders ........... | 11 | 2.1-13.1 | 6.6 | 1.6- 9.2 | 4.8 | 65-87 | 75 |
| Straws ............. | 4 | 0.7- 1. | 0.8 | 0.3- 0.8 | 0.6 | 42-80 | 64 |
| Fresh green roughages ......... | 9 | 0.7- 3.3 | 1.9 | 0.4- 2.2 | 1.3 | 55-87 | 69 |
| Silages .............. | 4 | 1.1- 2.6 | 1.7 | 0.6- 1.5 | 1. | 55-62 | 59 |

| | | Total digestible nutrients | | Therms | | Ratios of total digestible nutrients to therms | |
|---|---|---|---|---|---|---|---|
| | | Range | Ave. | Range | Ave. | Range | Ave. |
| | | % % | % | % % | % | 100: 100: | 100: |
| Grains and seeds.. | 13 | 63.4-85.9 | 78.4 | 59.7-93.7 | 80.6 | 94-116 | 102.6 |
| By-products* ..... | 11 | 65.7-88.9 | 76. | 53. -93.5 | 76.8 | 81-120 | 100.6 |
| By-products† ..... | 4 | 59.2-71.6 | 65.5 | 55.4-75.9 | 65.3 | 94-106 | 99.5 |
| Hay and dry coarse fodders.. | 11 | 46.1-53.7 | 50.5 | 31.6-51.2 | 40.2 | 67- 96 | 76.8 |
| Straws .......... | 4 | 36.9-45.6 | 41.6 | 7.2-36.6 | 24.1 | 20- 86 | 56.5 |
| Fresh green roughages ..... | 9 | 13.3-22.2 | 16.5 | 11.5-18.9 | 15.1 | 78- 98 | 91.7 |
| Silages .......... | 4 | 11.9-17.7 | 14.5 | 7.3-15.9 | 11.5 | 61- 90 | 77.5 |

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[1] Pa. Sta., Bul. 142 (1916).

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*Brewers' dried grains, cottonseed meals (choice and prime), corn distillers' dried grains, gluten feed, hominy feed, linseed meals (old and new processes), wheat bran, wheat middlings (flour and standard).

†Malt sprouts (62), molasses (beet and cane) (0), dried beet pulp (15).

A survey of this table would seem to justify the following very general statements:

1. *In grains, seeds and by-products* (exclusive of malt sprouts, molasses and beet pulp). Nine-tenths of the crude protein is true protein; and one percent of total digestible nutrients is equivalent to a therm.

2. *In hays and coarse dry fodders.* Three-fourths of the crude protein is true protein; and one percent of total digestible nutrients is equivalent to three-fourths of a therm.

3. *In fresh green roughages.* Two-thirds of the crude protein is true protein; and one percent of total digestible nutrients is equivalent to nine-tenths of a therm.

4. *In silages and straws.* Three-fifths of the crude protein is true protein and one pound of total digestible nutrients is equivalent to three-fourths of a therm (in silage) or three-fifths of a therm (in straw).

Obviously in order to convert, as it were, the Armsby and Eckles standard statements of true protein and therms into the crude protein and total nutrient terms of the Haecker, Savage or modified Wolff-Lehmann standards, one must know in any given case what roughages and concentrates are fed and, in a general way, in what proportions they are fed. In the trials now under consideration, the proportions of hay, silage and concentrates fed the 20 cows, stated on the total digestible nutrients basis, on the average approximated 42, 28 and 30. Using these three figures in connection with the Armsby analytical data, except as indicated by the * footnote, we have the following statement:

| | Proportion | Digestible crude protein | Digestible true protein | Total digestible nutrients | Therms | A × B + 100 | A × C + 100 | A × D + 100 | A × E + 100 |
|---|---|---|---|---|---|---|---|---|---|
| | A | B<br>% | C<br>% | D<br>% | E | | | | |
| Hay .......... | 42 | 4.57 | 3.06 | 50.97 | 41.38 | 1.92 | 1.29 | 21.42 | 17.38 |
| Silage ........ | 28 | 1.06 | 0.53 | 14.88 | 14.04 | 0.30 | 0.15 | 4.17 | 3.93 |
| Concentrates .. | 30 | 15.81* | 14.68 | 64.53 | 68.24 | 4.74 | 4.40 | 19.36 | 20.47 |
| | | | | | | 6.96 | 5.84 | 44.95 | 41.78 |
| | | | | | | 1.19 : | 1.00 | 1.08 : | 1.00 |

*Average of analyses of low, medium and high protein grain rations.

NOTE: Since this table is a most important one and since the ratios 1: 1.19 and 1: 1.08 are fundamental to the argument throughout the bulletin, it seems desirable to justify the data and explain their derivation.

***Digestible crude protein: total digestible nutrients: Hay.*** **[Averages 54 analyses mixed hay: 4.58, 51.43 (× 9) + average 12, 11 and 11 analyses of summer, oat and rowen hays 4.53, 46.80 (× 1)] ÷ 10. *Silage.* Average 56 analyses. *Concentrates.* Average 84 analyses.**

***Digestible true protein: net energy values (therms)*** **Armsby, Pa. Bul. 142, pp. 17-20. *Hay.* [Mixed timothy and clover 3.2, 41.07 (× 6) + timothy (early to full bloom), 2.5, 47.40 (× 1)] ÷ 7 × 0.986 to reduce to average dry matter content. *Silage.* 0.6, 15.90; × 0.883 to reduce to average dry matter content of silage fed. *Concentrates.* [Wheat bran, 10.8, 53.00 (× 8) + oats, 8.7, 67.56 (× 4¾), + hominy feed, 6.5, 81.31 (× 2), + gluten feed, 20.1, 80.72 (× 1), + cottonseed meal (prime), 32.0, 90.00 (× 3¼), + linseed meal (O. P.), 28.5, 88.91 (× 2)]; × 0.957 (true protein) to adjust to basis of the average digestible crude protein content of the three concentrate rations fed and × 0.982 (net energy values) to reduce to average dry matter content of the three concentrate rations fed.**

Applying these latter ratios to the Armsby and Eckles standards and comparing the results with the Haecker and the Savage standard statements, we have the following figures:

STANDARDS FOR MILK MAKING[1]

| For each pound of milk of a given fat percentage | Haecker (1914 form) | | Savage | | Eckles* (converted) | | Armsby* (converted) | |
|---|---|---|---|---|---|---|---|---|
| | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| **Maintenance (1,000 lb. cow)** | **0.7** | **7.925** | **0.7** | **7.925** | **0.595** | **6.48** | **0.595** | **6.48** |
| **2½** | **0.045** | **0.254** | **0.053** | **0.257** | .... | .... | **0.049** | **0.205** |
| **3** | **0.047** | **0.284** | **0.057** | **0.287** | **0.060** | **0.281** | **0.051** | **0.231** |
| **3½** | **0.049** | **0.313** | **0.061** | **0.319** | **0.062** | **0.302** | **0.054** | **0.257** |
| **4** | **0.054** | **0.343** | **0.065** | **0.350** | **0.065** | **0.324** | **0.058** | **0.286** |
| **4½** | **0.057** | **0.372** | **0.069** | **0.379** | **0.069** | **0.356** | **0.062** | **0.314** |
| **5** | **0.060** | **0.398** | **0.073** | **0.405** | **0.074** | **0.389** | **0.066** | **0.340** |
| **5½** | **0.064** | **0.424** | **0.077** | **0.431** | **0.079** | **0.432** | **0.069** | **0.365** |
| **6** | **0.067** | **0.451** | **0.081** | **0.457** | **0.083** | **0.486** | **0.073** | **0.390** |
| **6½** | **0.072** | **0.480** | **0.085** | **0.484** | **0.089** | **0.540** | **0.076** | **0.416** |
| **7** | **0.074** | **0.502** | **0.089** | **0.508** | .... | .... | **0.081** | **0.441** |

[1] No attempt is made in these standards to carry them to the final decimal. No attempt is made to publish, as do some of the authors, to the tenth of a percent. No attempt is made in their application in secs. V. to VIII. of this bulletin to calculate closer than one-fourth of one percent fat. In the writer's opinion the fourth decimal place is equivalent to lily painting and a tenth of a percent far within the limits of experimental error.

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* × 1.19 and × 1.08.

As has already been said, not only does disagreement exist in method of statement but likewise—and more important—disagreement as regards the nutrient needs of the cow. It seems best, therefore, to attempt to unify the method of statement so that in a general way one may indicate the divergencies between these several measuring rods. Accordingly, the tables on the next page have been prepared setting forth these differences. Taking the Haecker standard as unity, in general terms the other standards are related thereto as shown herewith.

### CROSS COMPARISONS OF STANDARDS—ARMSBY (CONVERTED) STANDARD COMPARED WITH

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients |
| Maintenance .. | —0.105 | —1.445 | —0.105 | —1.445 | 0. | 0. |
| 2½ percent.... | +0.004 | —0.049 | —0.004 | —0.052 | ..... | ..... |
| 3 percent.... | +0.004 | —0.053 | —0.006 | —0.056 | —0.009 | —0.050 |
| 3½ percent.... | +0.005 | —0.056 | —0.007 | —0.062 | —0.008 | —0.045 |
| 4 percent.... | +0.004 | —0.057 | —0.007 | —0.064 | —0.007 | —0.038 |
| 4½ percent.... | +0.005 | —0.058 | —0.007 | —0.065 | —0.007 | —0.042 |
| 5 percent.... | +0.006 | —0.058 | —0.007 | —0.065 | —0.008 | —0.059 |
| 5½ percent.... | +0.005 | —0.059 | —0.008 | —0.066 | —0.010 | —0.067 |
| 6 percent.... | +0.006 | —0.061 | —0.008 | —0.067 | —0.010 | —0.096 |
| 6½ percent.... | +0.004 | —0.064 | —0.009 | —0.068 | —0.013 | —0.124 |
| 7 percent.... | +0.007 | —0.061 | —0.008 | —0.067 | ..... | ..... |

### CROSS COMPARISONS OF STANDARDS—ECKLES (CONVERTED) STANDARD COMPARED WITH HAECKER AND SAVAGE; HAECKER COMPARED WITH SAVAGE

| | Haecker | | Savage | | Haecker compared with Savage | |
|---|---|---|---|---|---|---|
| | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients |
| Maintenance .. | —0.105 | —1.445 | —0.105 | —1.445 | 0. | 0. |
| 2½ percent.... | .... | .... | .... | .... | —0.008 | —0.003 |
| 3 percent.... | +0.013 | —0.003 | +0.003 | —0.006 | —0.010 | —0.003 |
| 3½ percent.... | +0.013 | —0.011 | +0.001 | —0.017 | —0.012 | —0.006 |
| 4 percent.... | +0.011 | —0.019 | 0. | —0.026 | —0.011 | —0.007 |
| 4½ percent.... | +0.012 | —0.016 | 0. | —0.023 | —0.012 | —0.007 |
| 5 percent.... | +0.014 | —0.009 | +0.001 | —0.016 | —0.013 | —0.007 |
| 5½ percent.... | +0.015 | +0.008 | +0.002 | +0.001 | —0.013 | —0.007 |
| 6 percent.... | +0.016 | +0.035 | +0.002 | +0.029 | —0.014 | —0.006 |
| 6½ percent.... | +0.017 | +0.060 | +0.004 | +0.056 | —0.013 | —0.004 |
| 7 percent.... | ..... | ..... | ..... | ..... | —0.015 | —0.006 |

### COMPARISONS OF STANDARDS ON THE PERCENTAGE BASIS— HAECKER STANDARD = 100

| | Digestible protein | | | | | Digestible dry matter | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Haecker | Savage | Eckles | Armsby | | Haecker | Savage | Eckles | Armsby |
| 3 | 100 | 121 | 128 | 108½ | 3 | 100 | 101 | 99 | 81 |
| 4 | 100 | 120 | 122 | 109 | 4 | 100 | 102 | 95 | 83½ |
| 5 | 100 | 122 | 123 | 109 | 5 | 100 | 102 | 98 | 85½ |
| 6 | 100 | 121 | 124 | 108 | 6 | 100 | 101½ | 108 | 86½ |
| 7 | 100 | 120 | ... | 109½ | 7 | 100 | 101 | ... | 88 |
| Average | 100 | 121 | 124 | 109 | Average | 100 | 101½ | 100 | 85 |

## COMPARISON BETWEEN THE STANDARDS FOR MILK PRODUCTION

The Haecker standard being rated as unity, the other three average:

*Digestible protein.* Savage, 21%, Eckles, 24%, Armsby, 9% high, with variations as follows: Savage, 20-22%; Eckles, 22-28%; Armsby, 2 to 10%.

*Total digestible nutrients.* Savage, 1½% high, Armsby, 15% low, Eckles, 0; with variations as follows: Savage, 1 to 2%, Armsby, 12 to 19%, Eckles, 5% low to 8% high.

However, the Haecker and Savage maintenance standards on the one hand and the Eckles and Armsby maintenance standards on the other are widely apart in the ratios, the latter being in respect to the former 15% low in digestible protein and 18% low in total digestible nutrients. Hence the maintenance and milk figures when used together are, as it were, a composite. The average calculated digestible protein and total digestible nutrient figures in the 46 comparisons in sections V. to VIII., inclusive, are:

*Digestible protein.* Armsby, 1.7, Haecker, 1.71, Savage, 1.90, Eckles, 1.87 pounds.

*Total digestible nutrients.* Armsby, 12.04, Haecker, 14.52, Savage, 14.62, Eckles, 13.04 pounds.

Rating the Haecker standard again as unity we have:

*Digestible protein.* Savage, 11% high, Eckles, 9% high, Armsby, ½% low.

*Total digestible nutrients.* Savage, 1% high, Eckles, 10% low, Armsby, 17% low.

This, of course, is a tantamount to saying in a very general way, so far as digestible protein is concerned, that on the one hand the Haecker and Armsby data tend to be comparable and, on the other, the Savage and Eckles data, the latter averaging about 10% high of the former. Furthermore, it is tantamount to saying in a general way, so far as total digestible nutrients are concerned, that the Haecker and Savage data tend to be comparable and that they tend to average 10 percent high of the Eckles and 17 percent high of the Armsby data. Stating this in another way, we find that the tendencies of the several standards as compared with each other are as follows:

| | In respect to digestible protein | In respect to total digestible nutrients |
|---|---|---|
| **Haecker** | **Low** | **High** |
| **Savage** | **High** | **High** |
| **Eckles** | **High** | **Low** |
| **Armsby** | **Low** | **Very low** |

# THE LITERATURE OF MAINTENANCE TRIALS WITH DAIRY CATTLE

In lieu of presenting at the close of the bulletin the usual bibliography, the writer has thought it advisable to attempt to review the literature and to present his review in advance of the discussion of the results of the long time trials which are set forth herewith. It is not thought that the list is exhaustive. It contains no reference to work reported upon during the past two years. It was prepared during the summer of 1920 and no opportunity has arisen since that time which permitted its further extension to cover literature published during 1920-1922. Access has not been had to the reports of some studies in foreign periodicals. Furthermore, while a reasonable degree of care was used in scanning the several indices, it well may be that some titles have escaped the writer's eyes. However, it is thought that the review, such as it is, may prove helpful in connection with the work presented in the bulletin.

Many metabolism and maintenance trials have been made with many classes of animals. Atwater and Langworthy's[1] monograph (1898) lists and discusses some 3,600 metabolism trials, including therein trials with 19 cows and 158 with steers. None of the trials with cows dealt with the matter of maintenance rations. Armsby[2] (1898) reviews the literature of exact experimentation as to the maintenance ration of cattle up to the date of issue and sets forth the results of eight trials made by him between 1892 and 1897 with three steers. No trials with cows are listed. Again in 1911[3] he discusses the literature of such trials to date but includes therein no statements as to trials with cows. However, in discussing the minimum of protein for farm animals[4] and, in another publication[5], the nutritive value of non-proteins in feeding stuffs, he cites several nitrogen balance and metabolism trials with milch cows.

The Experiment Station Record indices for Vols. I.-XII. (1889-1901) do not list maintenance trials with cows. However, Hagemann's[6] (1889) articles, dealing with "Investigations on the Metabolism of Milch Cows," discuss one trial in which the nitrogen balance of a milch cow was determined. The indices for Vols. XIII.-XXV. (1901-1911) and Vols. XXVI. to XLIII. (1912 to date) proved somewhat more fruitful. The following review is confined strictly to results secured with cows:

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[1] "A digest of metabolism experiments in which the balance of income and outgo was determined." U. S. Dept. Agr. Of. Exp. Sta. Bul. 45 (rev.) (1898).

[2] "The Maintenance Ration of Cattle." Pa. Sta. Bul. 42 (1898).

[3] U. S. Dept. Agr. Bu. An. Ind., Bul. 143, pp. 39, 47, 89, 94 (1911).

[4] Loc. Cit., pp. 89-94.

[5] U. S. D. A., B. A. I., B. 139, pp. 38-44 (1911).

[6] Exp. Sta. Rec. 10, pp. 803-816, 903-916 (1899).

Haecker (1900) notes the varying amounts of total dry matter used in the maintenance of barren non-milking cows differing in size and disposition, finding the usage per 1,000 pounds body weight to range from 10.8 pounds (for a restless, discontented cow weighing 708 pounds) to 12 pounds (for a quiet, contented cow, relatively fat, weighing 1,079 pounds) and considers that "in hypothecating a common factor as food of maintenance there may be introduced an element of error." *Minn. Sta. Bul. 67, p. 468 (1900); Abstr. E. S. R. 12, pp. 479-481 (1901).*

Marszalkowicz holds that, provided the 1,000-pound cow eats a sufficiency of digestible carbohydrates and 0.6 pound digestible protein, she does not need more than 0.0375 pound of digestible protein per pound of milk yield, a considerably lower figure than is suggested by any American student of nutrition, one which, furthermore, takes no account of the variations in the solid contents of milk. *Ztschr. Landw. Versuchs. Osters. 11, 8, pp. 669-700 (1908); Abstr. E. S. R. 20, p. 1074 (1909).*

Armsby (1910) in discussing the utilization of feed by beef cattle in the respiration calorimeter, points out "striking contrasts between our rations and the accepted standards (when a scrub and a pure breed steer) made entirely satisfactory gains on rations where digestible protein ranged (for a scrub steer) from 70 to 95 percent of the formulated requirements of the dairy breeds and (for a pure bred steer) from 50 to 70 percent of those of the beef breeds." He further and significantly says that "the tendency of recent investigations is to show that in all branches of feeding the minimum protein requirement has been considerably exaggerated. This has been shown to be true of the maintenance requirement and of the requirement for milk production, while our results suggest that it is also true for growth." *Penn. Sta. Bul. 105, pp. 21-22 (1910); Abstr. E. S. R. 24, pp. 468-470 (1911).*

Eckles and Reed (1910-) have made several maintenance studies using dairy cows. In one of these trials four registered Jerseys, half-sisters, were employed, three of them being good producers and one inferior. They were fed while farrow for from 120 to 180 days apiece. Their live weights were held essentially uniform. These four cows consumed daily averages of 5,791, 5,534, 4,907 and 4,792 calories. Three of the cows approximated 900 pounds in weight, the fourth 800 pounds. A fifth cow, likewise a Jersey, averaging to weigh about 750 pounds, was fed a ration somewhat lower in digestible protein—one used for and calculated for the growing and fattening of steers. The four cows seem to have received the following daily average amounts of digestible protein and digestible nutrients: 0.9, 6.71; 0.86, 6.43; 0.75, 5.7; 0.75, 5.68.

As a result of these five trials of maintenance *per se*, the authors conclude that the cows they had under experiment conformed in their usage of fat closely to the amounts suggested by Armsby and Haecker in their average maintenance requirements standards; the comparative figures on the basis of therms being: Armsby's: 6 therms; 4 Jerseys, 6.08 therms. Haecker's: calculated to therms, 8.42 therms; 4 Jerseys, 8.61 therms.

The first four cows were also under trial while in milk, each being kept under observation and in milk for a full year. Their average daily food usage and milk solid and fat yields were as follows:

| Digestible protein | Total digestible nutrients | Calories | Milk | Total solids | Fat |
|---|---|---|---|---|---|
| lbs. | lbs. | | lbs. | lbs. | lbs. |
| 3. | 22.85 | 13,074 | 18.6 | 2.72 | 1.02 |
| 3.35 | 25.5 | 14,613 | 23.4 | 3.47 | 1.29 |
| 3.05 | 23.2 | 13,222 | 16.5 | 2.55 | 1.01 |
| 1.89 | 14.25 | 8,240 | 8.7 | 1.27 | 0.46 |

The digestible protein usage of three of the four cows was excessive, being on the 1,000-pound basis from 3.35 to 3.75 pounds daily—amounts much larger than are suggested by any standard known to the writer (J. L. H.) for cows giving relatively small amounts of milk.

It is interesting to note that if the calories used for maintenance purposes be subtracted from the calories used while in milk, the almost identical figures are secured, if one calculates the number of calories used to make a pound of milk. This is true with three of the four cows, the figures being 1: 392, 1: 288, 1: 504 and 1: 396. In short, in three cases, including the inferior cow, it took practically 390 calories to make a pound of milk. Indeed the authors point out that the inferior cow used more of her somewhat restricted ration for maintenance purposes and that when this amount was deducted from the total, she used the residue of her food intake in milk making as economically as did two of her half-sisters and more economically than did one of them.

It is further interesting to note that this inferior cow, shortly after the opening of her next lactation, being very heavily fed, did not increase her milk yield; that, in other words, her low yields were due to bovine idiosyncrasy and not to restricted rationing.

The digestion trials made with three of these cows while on maintenance and again while on a full milk ration and giving milk seem to indicate that digestion coefficients tend to range higher in the former case than in the latter. The authors point out that average digestion coefficients may be found somewhat high for use with heavily fed milch cows. *Mo. Sta. Rsch. Buls. 2, 4, 5 (1910-1911); Abstr. E. S. R. 24, p. 76; 26, pp. 476-477 (1912).*

Eckles (1916) fed 6 cows during an entire gestation period on rations found to be, for these particular animals, exactly maintenance rations. These animals dropped normal sized calves and, on the whole, maintained weight; indeed, some gained in weight.

The author points out the small amount of dry matter contained in the fœtus and its accompanying ejecta. He further indicates the possibility of decreased maintenance calls upon the food upon the part of the bovine mother, due to her more quiet life during pregnancy. He points out in brief that the weight of the calf at birth is not ordinarily influenced by the ration received by the animal during gestation unless, perchance, the ration be decidedly deficient for a long period of time in some one constituent. This all amounts to the same thing as saying that "the amount of feed required to develop the fœtus is so small that it cannot be measured by weighing the animal and taking weights and amounts of the feed. In other words, the fœtus may be developed on a maintenance ration. A cow in producing about 200 pounds of milk produces as much dry matter and of much the same composition, except in regard to ash * * * as would be required to develop the fœtus."

Trowbridge, Moulton and Haigh (1915) found in studies of maintenance of beef cattle, extending over several years, that the condition of the animal seems to exert no effect upon the cost of maintenance; that a previous liberal ration tends to accentuate the cost of maintenance *per se;* that it is least in the spring, greatest in the winter and intermediate in summer and fall; that increasing age tends to decrease the cost of maintenance and that in a long continued maintenance trial this is a contributary cause to the lowered result; that increased activity augments maintenance costs; that poor thrift and high maintenance costs seem to go together; and that the heavier the animal the greater the proportional maintenance costs for two reasons, its increased weight and its relatively smaller surface area.

It seems to the writer (J. L. H.) that some of these deductions are likely to have bearing upon and should be borne in mind in the interpretation of the results of the long continued trials reported upon in this bulletin. *Mo. Sta. Rsch. Bul. 18 (1915). Abstr. E. S. R. 33, pp. 569-570 (1915).*

Hagemann (1899) calculates the fœtal draft as follows: weight of calf 88 lbs. including 57 lbs. water, 5½ lbs. ash, 3½ lbs. fat and 22 lbs. protein. Assuming an unchanged daily draft—obviously an unwarranted assumption —and 284 days gestation, 1¼ oz. protein is needed each day, exclusive of the amount needed anabolically, which the author puts at 20 percent, making the average daily draft on the mother equivalent to 1½ oz. It is stated that this is about the draft made at the end of the fourth month of pregnancy and constitutes but 8 percent of the total amount needed directly for milk making and fœtal construction by a cow making 26½ lbs. milk. The draft in the form of fœtal fat construction would be about 2/10 of an ounce. *Exp. Sta. Rcd. 10, pp. 914-915 (1899).*

Gavin examined 1,421 records with a view of determining the maximum day-yield and the time after service when fœtal growth affects yield. He finds the diminution in milk yield "very rapid" 16 weeks after service. *Jour. Ap. Sci. 5, 3, pp. 309-319 (1913); Abstr. E. S. R. 29, p. 577 (1913).*

Evvard (1912-1913) fed pregnant sows and ewes with divers rations including straight corn meal or ear corn and various supplements thereto. The increase in protein and ash in certain supplemented rations tended decidedly to increase the size and strength of the newborn pigs and to produce stronger and larger lambs. *Breeder's Gaz. 61, 7, p. 395 (1912); Amer. Bdrs'. Assoc. 8, pp. 549-560 (1912); Proc. Iowa Acad. Sci. 20, pp. 325-330 (1913). Abstr. E. S. R. 27, p. 279 (1912); 28, pp. 574, 575 (1914); 29, pp. 266-267 (1915).*

Russell (1914) estimates that the pregnant 1,000-pound cow giving an average of 25 pounds daily will need approximately 2 ounces of lime daily for milk and fœtus, an amount supplied by the hay and silage (or stover) in the amounts ordinarily eaten but not supplied by straw. An animal stinted in its lime intake may and usually does make draft upon the body supply of calcium up to 20 or more percent. *Wis. Sta. Bul. 240, p. 33 (1914); Abstr. E. S. R. 31, p. 864 (1915).*

Eckles (1916) in the introduction to his bulletin dealing with the nutrients required to develop the bovine fœtus cites considerable literature dealing with the studies of various parties in connection with the nutriment of the maternal tissues in the construction of the fœtuses of the human.

guinea pig, rat and pig. The consensus of opinion of the authors quoted seems to be, so be it the ration is reasonably well balanced in respect both to its organic and inorganic nutrients and in respect to the variety of the proteins furnished, that: fœtal construction does not seriously tax the tissues of the mother; that in accordance with one investigator, "the nourishment of the mother tissues seems to take precedence over the nutrition of the fœtus"; in accordance with another, that "gestation does not represent a tax upon the mother but acts as a stimulus"; in accordance with the statements of another, that "during the earlier stages of pregnancy, the influence upon the growth of the mother animal is favorable and a more energetic metabolism induced." *Mo. Rsch. Bul. 26 (1916); Abstr. E. S. R. 37, pp. 71-72 (1916).*

Armsby (1912) discusses at length the protein requirement for maintenance. He points out how comparatively small is the "amount of protein katabolized in the fasting animal * * * (which, under certain circumstances, is) absolutely essential to the vital processes" and states that provided the ration furnishes enough carbohydrates "a supply of protein equivalent to the fasting protein katabolism is sufficient to meet the needs of the organism" and, again, that "the protein requirement upon a mixed ration sufficient in quantity is comparatively small." He refers to the oft-proved fact that increased digestion by the mature animal of digestible protein in excess of this irreducible minimum serves in the main simply to increase protein katabolism, the excess passing from the body, in the case of milking animals, partly in the milk but mostly in the urine.

He cites experimental evidence tending to prove the value of the non-proteins for maintenance purposes, their lack of value in production, and makes cogent statements as to the physiological protein minimums and the optimums. He indicates as a minimum from 0.4 to 0.6 pounds per 1,000 pounds of live weight for all classes of farm animals with the average for cattle at the upper limit with a 0.1 to 0.2 pound leeway on either side; and cites here and in another bulletin the results of several trials with dry and with milking cows as to their protein requirements. He qualifies his statement, however, by saying that "for actual maintenance feeding it is probable that a somewhat more liberal supply of protein than is indicated would be advisable" on the ground that "the digestion of the non-nitrogenous nutrients from such protein-poor rations would be apt to be injuriously affected."

Touching optimums, the most advantageous level of protein nutrition, he states (referring to the protein requirements of the mature animals) that "it can not be said that a considerable surplus of protein over the minimum requirement for maintenance, that is, the maintenance of protein nutrition on a high plane, has been proved to be of any material advantage during periods covering several months." However, he states that long continued low protein diets, i. e., for years or generations, might result in impaired physical condition and that this possibility should be borne in mind.[1] *U. S. Dept. Agr., Bu. An. Ind., Buls. 139, pp. 32-49 (1911); 143, pp. 39-47, 74-81, 88-94, 97-99 (1912). Abstr. E. S. R. 26, pp. 71-72, 664-665 (1912).*

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[1] The results secured in the Vermont trials and reported in bulletin 225 are significant in this connection.

## I AND II. MAINTENANCE

### I. MAINTENANCE FOR LESS THAN 12 MONTHS

Only three records contribute to this phase of the study. One of these records (I. 3.) is of little value, if not, indeed, misleading and another (I. 2.) is badly vitiated by the loss of the weight data as set forth on pages 11-12.

It should be noted that in all the comparisons to be made from this point onwards in the bulletin in Sections I to VIII, inclusive, wherein the actual food consumption in terms of digestible crude protein and total digestible nutrients is referred to statements as to standards, the Haecker, Savage, Armsby (converted) and Eckles (converted) standards are intended. Furthermore, in order to save space and to obviate the wearisome repetition of such phraseology as "more than standards indicate," "less than standards called for" and the like, the phraseology "excess of" or "deficiency of" will be usually employed—it being understood in each instance that reference is had to these standards. At times when there is need to refer to the standards in table captions, the appropriate initials (H), (S), (A) and (E) will be employed.

I. 1. ALTJE, grade Holstein, 12 years old, while dry and barren was fed the medium protein ration for 93 days from February 5 to May 9, 1914. Her feeding records were as follows:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 8 | 10 | 30 | 2 | 5 | 10 | 30 | 4 |

She ate, as compared with standards, much more food than was needed, as appears below:

| Weeks | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. | Weeks | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. | | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. |
|---|---|---|---|---|---|---|---|---|
| 8 | 1.05 | 10.25 | 5 | 1.35 | 11.6 | Ave. | 1.15 | 10.8 |

Her excess of nutrient intake over that indicated by the standards for maintenance ranged from +½ to +5/4 for digestible protein and from +3/10 to +⅘ for total digestible nutrients. Her average live weights for successive two-week periods, including the week of service, were: 1,177, 1,194, 1,214, 1,212, 1,238, 1,247, 1,249 pounds. Her gain in live weight was about 6 percent. Altje was more than maintained by the ration which she received.

I. 2. NESBIT, grade Jersey, nine years old, while dry and barren, was fed the high protein ration for 178 days, December 31, 1916 to June 26, 1917. Her feeding record follows:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| $2^5/_7$ | 10 | 21 | .. | $3^6/_7$ | 6 | 12 | 3.6 |
| 19 | 8 | 16 | 4.8 | ... | .. | .. | .. |

Nesbit was fed an essentially standard maintenance ration during the initial three weeks of this particular trial, but super-standard rations when grain was added. During the last period, however, standard feeding conditions were more nearly approximated, as appears below:

| | | | As compared with standards | | | |
|---|---|---|---|---|---|---|
| | | | H., S., etc. | | A., E. (conv.) | |
| Weeks | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | % | % | % | % |
| $2^5/_7$ | 0.6 | 7.8 | — 14 | — 2 | + 1 | +20 |
| 19 | 1.5 | 10.4 | +114 | +31 | +152 | +60 |
| $3^6/_7$ | 1.05 | 7.2 | + 50 | — 9 | + 77 | +11 |

Owing to the loss of the weight records, no definite statements can be made as to the effect of the variation in feeding upon live weight. Nesbit probably averaged to weigh in the vicinity of 960 pounds.

I. 3. KARAH, after five years of service in these trials, went dry while barren on June 24 and was served October 3, 1920. She was fed the low protein ration for 101 days while dry and received a bountiful supply; indeed, her nutrient intake was as liberal as that which she normally would receive when in full flow. She ate 20.3 pounds of total dry matter; 1.3 pounds of digestible protein; 13.1 pounds of total digestible nutrients.

In explanation of this anomalous sort of feeding it may be said that Karah had shrunk greatly in live weight during the last two months of her previous lactation, her average weights for four successive four-week periods being 894, 899, 824, 819 pounds. The writer, otherwise engaged, failed to give proper oversight to what was going on at this point; and the barn foreman temporarily in charge conceived it to be his particular duty to restore her to normality in respect to her physical condition, with results in successive four-week periods as follows: 840, 881, 901, 895, 920 pounds. Thus it happens that Karah's so-called maintenance trial became really not a maintenance but a fattening period.

## II. MAINTENANCE FOR GREAT LENGTHS OF TIME, IN EXCESS OF 12 MONTHS AND AVERAGING 28 MONTHS

Twenty different cows were fed for from 396 to 2,701 days. Four were fed approximately 400 days, four approximately 500, two approximately 600, one approximately 700, two approximately 800, one approximately 900, one approximately 1,000, two approximately 1,100, two approximately 1,500 and one for 2,701 days. Two were registered and one a grade Ayrshire, four were grade Holsteins and 13 were grade Jerseys. They weighed on the average from 820 to 1,295 pounds live weight and averaged nearly 1,000 pounds apiece. The mean statement as to their food usage, per 1,000 pounds live weight, was: Total dry matter, 10.88 pounds; digestible dry matter, 6.88 pounds; digestible protein, 0.84; digestible carbohydrates and fat, 6 pounds.

II. 1. ALTJE, grade Holstein, seven years old, while dry and barren was fed the medium protein ration for 396 days, December 10, 1908 to January 10, 1910. Her food intake was essentially as follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 15 | 8.4 | 14.1 | 5.4 | 14 | 5.7 | 12.5 | 3.1 |
| 14 | 6.2 | 12.6 | 4. | 14 | 5. | 10. | 2.8 |
| 14 | 6. | 12.5 | 3.4 | 14 | 6.7 | 13.6 | 3.6 |

Her food usage and the comparison thereof with standard requirements appear below:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 15 | 16.9 | 10.9 | 1.45 | 9.35 | 10.8 | 13.4 | 8.7 | 1.1 | 7.5 | 8.6 | 1,257 | +57 | +85 | + 9 | +33 |
| 14 | 13. | 8.4 | 1.1 | 7.25 | 8.35 | 10. | 6.5 | 0.85 | 5.5 | 6.4 | 1,289 | +21 | +43 | —19 | 0 |
| 14 | 11.9 | 7.7 | 1.1 | 6.4 | 7.5 | 9. | 5.8 | 0.85 | 4.9 | 5.8 | 1,305 | +21 | +43 | —27 | —11 |
| 14 | 10.4 | 6.7 | 1. | 5.6 | 6.6 | 7.8 | 5.1 | 0.75 | 4.2 | 5. | 1,329 | + 7 | +26 | —36 | —22 |
| Ave. | 13.15 | 8.5 | 1.15 | 7.2 | 8.4 | 10.15 | 6.55 | 0.89 | 5.55 | 6.5 | 1,295 | +29 | +50 | —18 | + 1 |
| Standards: Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards: Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |
| Succeeding service | | | | | | | | | | | | | | | |
| 14 | 9.3 | 6. | 0.8 | 5. | 5.8 | 7.1 | 4.6 | 0.6 | 3.8 | 4.4 | 1,312 | —14 | + 1 | —43 | —31 |
| 14 | 12.7 | 8.2 | 1.05 | 7. | 8.05 | 9.4 | 6.1 | 0.8 | 5.2 | 5.95 | 1,352 | +14 | +34 | —24 | — 7 |

*First period.* Altje ate 3/5 to 5/6 excess of digestible protein but her total digestible nutrient intake was from 1/10 to 1/3 deficient. She gained 5 percent in live weight.

*Second period.* She ate 1/5 to 3/7 excess of digestible protein and her total digestible nutrient intake was from 0 to 1/5 excessive. She maintained an essentially unchanged weight throughout the period.

*Third period.* She ate 1/5 to 3/7 excess of digestible protein but her total digestible nutrient intake was from 1/10 to 1/4 deficient. She gained 1 percent in live weight and held her gain.

*Fourth period.* She ate 1/14 to 1/4 excess of digestible protein but her total digestible nutrient intake was from 1/5 to 3/8 deficient. She gained 1 percent over her weight at the end and 2 percent over her average weight during the preceding period, weighing 6 to 8 percent more than at the outset.

*Average.* She ate 3/10 to 1/2 excess of digestible protein but her total digestible nutrient intake was from 0 to 1/5 deficient; and she gained 8 percent in live weight.

Altje seemed none the worse for her 400 days of somewhat restricted diet. Indeed, following service, she was fed a yet lower ration for 100 days (*fifth period*) in which digestible protein was lacking to the extent of from 0 to 1/7 and total digestible nutrients were 3/10 to 3/7 short; yet she dropped only 1 percent in weight. During the next 100 days (*sixth period*) her food intake closely approximated that of the second period, i. e., 1/7 to 1/3 excess of digestible protein, but 1/14 to 1/4 deficiency of total digestible nutrients; and she gained in weight as was to be expected, since she was in mid-gestation. She aborted at 6½ months, yet she gave during the succeeding year almost 10,000 pounds of milk and 327 pounds of fat. She remained in the trials for five more years, doing good service.

II. 2. BONTJE, grade Holstein, eight years old, was fed the low protein ration for 477 days, March 29, 1910 to July 15, 1911. She was overfed during the first quarter and underfed during the last three-fifths of the trial, as judged by the standards. Her feeding record was as follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 4 | 15. | 4.4 | 1. | 18 | 4.2 | 12.5 | 2. |
| 14 | 15. | 20. | 4. | 5 | 4. | 12.5 | 3. |
| 9 | 12. | 12.5 | 3. | 9 | 8. | 12.5 | 3. |
| 23 | 7. | 12.5 | 3. | | | | |

The statement as to feeding, live weights, comparisons with standards, arranged as in the case of Altje, follows:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 4 | 15.3 | 9.3 | 0.85 | 7.9 | 8.8 | 15.9 | 9.7 | 0.9 | 8.2 | 9.2 | 960 | +29 | +51 | +19 | +45 |
| 14 | 22.5 | 14.1 | 1.3 | 12.4 | 13.7 | 20.1 | 12.6 | 1.15 | 11.1 | 12.2 | 1,121 | +64 | +93 | +56 | +90 |
| 9 | 16.5 | 10.4 | 1.1 | 9.1 | 10.2 | 13.9 | 8.7 | 0.9 | 7.6 | 8.6 | 1,187 | +29 | +51 | + 9 | +33 |
| 23 | 11.4 | 7.3 | 0.8 | 6.4 | 7.2 | 9.4 | 6. | 0.65 | 5.3 | 6. | 1,208 | — 7 | + 9 | —24 | — 7 |
| 18 | 8.5 | 5.5 | 0.55 | 4.8 | 5.4 | 7.25 | 4.6 | 0.45 | 4. | 4.5 | 1,194 | —36 | —24 | —43 | —31 |
| Ave. | 13.85 | 8.7 | 0.88 | 7.65 | 8.55 | 11.75 | 7.4 | 0.75 | 6.5 | 7.3 | 1,175 | + 6 | +26 | — 7 | +13 |
| Standards: Haecker, Savage, modified | | | | | | | | | | | | | | | |
| Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards: Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |
| Following service | | | | | | | | | | | | | | | |
| 5 | 9. | 5.9 | 0.6 | 5.3 | 5.9 | 7.6 | 5. | 0.5 | 4.5 | 5. | 1,192 | —29 | —16 | —37 | —23 |
| 9 | 12.2 | 7.8 | 0.75 | 7. | 7.7 | 10. | 6.4 | 0.6 | 5.7 | 6.3 | 1,220 | —14 | + 1 | —20 | — 2 |

*First period.* Bontje ate during 4 weeks 3/10 to 1/2 excess of digestible protein and 1/5 to 3/7 excess of total digestible nutrients and gained 3 percent in live weight. She had been subjected to a very low food intake immediately preceding this period.

*Second period.* She ate during 14 weeks 2/3 to 9/10 excess of digestible protein and 4/7 to 9/10 excess total digestible nutrients. She gained very rapidly in live weight throughout the 14 weeks, averaging a 17 percent gain over the medial weight of the preceding period.

*Third period.* She ate during nine weeks 3/10 to 1/2 excess of digestible protein and 1/10 to 1/3 excess of total digestible nutrients. She gained 2 percent in live weight during the period and 6 percent over the medial weight of the preceding period.

*Fourth period.* She ate during 23 weeks closely standard amounts of digestible protein, i. e., from 1/14 deficiency to 1/10 excess, while her intake of total digestible nutrients was deficient by from 1/14 to 1/4. Yet, notwithstanding, she gained 4 percent in live weight during the period and 2 percent over the medial weight of the preceding period.

*Fifth period.* She ate during 18 weeks from $\frac{1}{4}$ to $\frac{3}{8}$ less digestible protein and from $\frac{3}{10}$ to $\frac{3}{7}$ less total digestible nutrients than standards indicated; and she dropped 2 percent in live weight at the outset and 5 percent at the close of the period as compared with her average weight at the close of the preceding period. However, she lost only 1 percent in live weight if one compares the average of the entire period 18 weeks long with the average live weight during the preceding 23 weeks.

*Average.* She ate from $\frac{1}{16}$ to $\frac{1}{4}$ excess of digestible protein but her total digestible nutrients intake was deficient by $\frac{1}{14}$ according to one and excessive by $\frac{1}{8}$ according to another standard, and she gained more than $\frac{1}{10}$ in live weight.

*Following service. Sixth period.* During the first five weeks she ate $\frac{1}{8}$ to $\frac{3}{10}$ less digestible protein and $\frac{1}{4}$ to $\frac{3}{8}$ less total digestible nutrients than the standards indicated and maintained an unchanged weight.

*Seventh period.* During the ensuing nine weeks to the close of the first third of gestation her food intake was deficient 0 to $\frac{1}{7}$ in digestible protein and 0 to $\frac{1}{5}$ in total digestible nutrients; yet she gained 2 percent in live weight.

Bontje calved normally at full time and during the ensuing 10 weeks averaged 40 pounds of milk a day. She continued in good health for four years more.

II. 3. Durtje, grade Holstein, six years old, was fed the high protein ration for 408 days, December 3, 1908-January 15, 1910. Her records during 16-, 9-, 17- and 16-week periods prior to service and during 14-, 4- and 9-week periods subsequent to service appear below. Her feeding record was essentially as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 16 | 8.4 | 12.5 | 5. | 14 | 5. | 11.4 | 2.8 |
| 9 | 5. | 9.8 | 3.6 | 4 | 6. | 12.5 | 3. |
| 17 | 4.8 | 10. | 2.4 | 9 | 7. | 14.4 | 4. |
| 16 | 5.7 | 14.4 | 3. | | | | |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 16 | 15.9 | 10.4 | 1.7 | 8.5 | 10.2 | 12.6 | 8.3 | 1.35 | 6.8 | 8.1 | 1,257 | +93 | +127 | + 3 | +26 |
| 9 | 10.6 | 6.9 | 1.15 | 5.8 | 6.95 | 8.3 | 5.4 | 0.9 | 4.5 | 5.4 | 1,282 | +29 | + 51 | —32 | —17 |
| 17 | 9.3 | 6. | 0.95 | 5. | 5.95 | 7.5 | 4.8 | 0.75 | 4. | 4.8 | 1,244 | + 7 | + 26 | —39 | —26 |
| 16 | 10.6 | 6.8 | 1.15 | 5.5 | 6.65 | 8.5 | 5.4 | 0.9 | 4.4 | 5.3 | 1,251 | +29 | + 51 | —33 | —18 |
| Ave. | 11.7 | 7.6 | 1.25 | 6.3 | 7.6 | 9.3 | 6. | 0.98 | 5. | 6. | 1,254 | +40 | + 65 | —24 | — 8 |
| Standards: Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards: Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |
| Following service | | | | | | | | | | | | | | | |
| 14 | 9.6 | 6.2 | 1. | 5.1 | 6.1 | 7.6 | 4.9 | 0.8 | 4. | 4.8 | 1,263 | +14 | + 34 | —39 | —25 |
| 4 | 11.5 | 7.4 | 1.15 | 6.2 | 7.35 | 9. | 5.8 | 0.9 | 4.8 | 5.7 | 1,284 | +29 | + 51 | —28 | —11 |
| 9 | 13.1 | 8.6 | 1.35 | 7.1 | 8.45 | 9.9 | 6.5 | 1. | 5.3 | 6.4 | 1,328 | +43 | + 68 | —19 | 0 |

*First period.* She ate during 16 weeks $^{9}/_{10}$ to $^{5}/_{4}$ excess of digestible protein, and 0 to $^{1}/_{4}$ excess of total digestible nutrients, and gained 7 percent in live weight.

*Second period.* She ate during 9 weeks $^{3}/_{10}$ to $^{1}/_{2}$ excess of digestible protein but her total digestible nutrient intake was deficient by $^{1}/_{6}$ to $^{1}/_{3}$. She gained 2 percent in live weight on the average as compared with the average of the preceding period, losing, however, 2 percent in live weight during the course of the period.

*Third period.* She ate during 17 weeks an excess of $^{1}/_{14}$ to $^{1}/_{4}$ digestible protein but her total digestible nutrient intake was deficient by from $^{1}/_{4}$ to $^{2}/_{5}$. She lost 3 percent in live weight on the average as compared with that of the former period and 2 percent during the period, weighing at its close 7 percent less than she did six months previous at the close of her 16-week period, during which she ate double the standard amount of digestible protein and a full standard ration of total digestible nutrients.

*Fourth period.* The cow ate during 16 weeks a ration similar in all respects to that eaten in the second period (+3/10 to +1/2, —1/6 to —1/3) and gained 5 percent in live weight during the four months, averaging at the end of the period a 1 percent gain in live weight over the average of the preceding period.

*Average.* Her average food intake was 2/5 to 2/3 excessive in respect to digestible protein but 1/10 to 1/4 deficient in respect to its total digestible nutrient content. She maintained a reasonably uniform live weight.

*Following service. Fifth period.* She ate during 14 weeks a ration closely similar in all respects to that eaten in the third period (+1/7 to +1/3, —1/4 to —2/5) and had dropped 2 percent in live weight at its close but gained 1 percent during the period as compared with its predecessor.

*Sixth and seventh periods.* Increased yet, according to standards, insufficient food supplies (+3/10 to +2/3, 0 to —3/10) and advancing gestation naturally caused consistent increments in live weights.

Durtje calved normally, gave approximately 8,700 pounds of milk and 318 pounds of fat during the following year and remained on service in the trial for two years following the close of the maintenance test when, losing half her udder, she was discarded.

II. 4. HAZEL K., grade Jersey, five years old, remained dry and farrow for 502 days, July 14, 1908-November 28, 1909. She was fed the low protein ration. Her records as to food intake and her live weights are shown in the following table. During the three weeks immediately following her drying off she was fed 16 to 19 pounds of hay daily but no silage or grain. Her feeding record was as follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|
| 3 | 18. | .. | .. |
| 15 | 12. | .. | 4.6 |
| 19 | 6.9 | 9.6 | 3.6 |
| 8 | 3.5 | 6.7 | 3. |
| 11 | 3. | 5. | 2. |
| 16 | 4. | 7.9 | 2.3 |
| 21 | 5. | 10. | 2.8 |
| 19 | 5. | 12.5 | 3. |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 3 | 14.9 | 9. | 0.8 | 7.9 | 8.7 | 15.3 | 9.25 | 0.8 | 8.1 | 8.95 | 975 | +14 | +34 | +15 | +40 |
| 15 | 14.8 | 9.3 | 1. | 8.4 | 9.3 | 15.1 | 9.5 | 1. | 8.6 | 9.5 | 978 | +43 | +68 | +20 | +47 |
| 19 | 12.3 | 7.9 | 0.8 | 7. | 7.8 | 11.9 | 7.7 | 0.8 | 6.9 | 7.7 | 1,034 | +14 | +34 | — 3 | +19 |
| 8 | 8. | 5.2 | 0.55 | 4.6 | 5.15 | 7.6 | 5. | 0.5 | 4.4 | 4.9 | 1,050 | —29 | —16 | —38 | —24 |
| 11 | 6. | 3.9 | 0.45 | 3.4 | 3.85 | 6. | 3.9 | 0.45 | 3.4 | 3.85 | 1,004 | —36 | —24 | —51 | —40 |
| 16 | 7.2 | 4.55 | 0.5 | 4. | 4.5 | 7.3 | 4.6 | 0.5 | 4.05 | 4.55 | 990 | —29 | —16 | —42 | —29 |
| Ave. | 10.63 | 6.75 | 0.7 | 6. | 6.7 | 10.55 | 6.7 | 0.7 | 5.95 | 6.65 | 1,008 | 0 | +18 | —16 | + 3 |
| Standards: Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards: Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |
| Following service | | | | | | | | | | | | | | | |
| 21 | 9.1 | 5.8 | 0.6 | 5.2 | 5.8 | 9.1 | 5.8 | 0.6 | 5.2 | 5.8 | 1,004 | —14 | + 1 | —27 | —11 |
| 19 | 10.7 | 6.9 | 0.7 | 6.1 | 6.8 | 9.8 | 6.4 | 0.65 | 5.6 | 6.3 | 1,085 | — 7 | + 9 | —20 | — 2 |

*First period.* Hazel K. ate during 15 weeks 3/7 to 2/3 excess of digestible protein and 1/5 to 1/2 excess of total digestible nutrients. She held her weight at an essentially constant figure. Notwithstanding her relatively high food intake, she shrank in live weight as compared with her average weight during the 10 weeks of lactation immediately preceding drying off when she ate 1/3 less food and weighed 4 percent more. This anomalous result seems more remarkable when one notes her increase in weight when fed a more restricted ration during the second and third periods.

*Second period.* She ate during 19 weeks 1/7 to 1/3 excess of digestible protein and from 0 to 1/5 excess of total digestible nutrients: and yet, notwithstanding this lessened food intake, she promptly increased in live weight and maintained the same on a consistently higher plane for 27 weeks on the lowered ration than she had on the more liberal one. At no time did she seem off feed, in ill health, or in any wise abnormal during either period. Her average gain in live weight during the second period amounted to 6 percent.

*Third period.* She ate during 8 weeks a ration deficient in respect to digestible protein by from 1/6 to 3/10 and in respect to total digestible nutrients by 1/4 to 3/8, yet she gained 2 percent in weight as compared with her average live weight during the 19 weeks of standard or better than standard feeding. However, she began to drop a little in flesh during the latter half of the period.

*Fourth period.* She ate during 11 weeks a ration deficient in respect to digestible protein by 1/4 to 3/8 and in respect to total digestible nutrients by 2/5 to 1/2; and she lost weight consistently, dropping more than 5 percent during the course of the period and 4 percent on the average.

*Fifth period.* She ate during 16 weeks a little more than during the third period, the shortages in digestible protein and in total digestible nutrients being, respectively, 1/6 to 3/10, 3/10 to 3/7. She maintained her live weight fairly well for 12 weeks but dropped slightly during the last four weeks, losing 1 percent as compared with the former average.

*Average.* Her food intake was 0 to 1/6 in excess in respect to digestible protein and 0 to 1/6 deficient in respect to total digestible nutrients; and she gained 3 percent in live weight.

*Following service. Sixth period.* During the first half of gestation her ration was short of standard requirements by 0 to 1/7 digestible protein and 1/10 to 1/4 in total digestible nutrients; but she gained somewhat in weight, as was to be expected, and averaged to weigh essentially the same as during the average of the preceding 27 weeks.

*Seventh period.* During the latter half of gestation she ate a ration furnishing an essentially standard digestible protein content for mere maintenance (—1/14 to +1/10) but short from 0 to 1/5 in its total digestible nutrient content; yet she increased in weight—as was to be expected—and she calved normally at full time, dropping a healthy and full sized bull calf.

Hazel K. yielded during the succeeding year nearly 5,650 pounds of milk and 302 pounds of fat and continued doing good service in these trials for more than five years.

II. 5. JANE, grade Jersey, five years old, was fed while dry and farrow for 424 days from July 9, 1908 to September 7, 1909, the high protein ration being used. Her record as to food intake and live weights is shown in the subjoined table. Her feeding record before and after service was as follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 3 | 18. | .. | .. | 8 | 2.4 | 5. | 1.3 |
| 14 | 12. | .. | 4.6 | 6 | 3.7 | 7. | 2. |
| 3 | 9.3 | 3.9 | 0.4 | 6 | 3. | 7. | 2. |
| 17 | 4.3 | 8.9 | 3.2 | 8 | 3. | 5. | 2. |
| 9 | 3.3 | 7.4 | 2. | 16 | 3. | 7. | 2. |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 3 | 14.9 | 9. | 0.8 | 7.9 | 8.7 | ... | .. | .. | .. | .. | * | ... | ... | .. | .. |
| 14 | 14.8 | 9.5 | 1.6 | 7.8 | 9.4 | 18.7 | 12. | 2. | 9.9 | 11.9 | 790 | +186 | +236 | +51 | −84 |
| 3 | 9. | 6. | 0.55 | 5.3 | 5.85 | ... | .. | .. | .. | .. | * | ... | ... | .. | .. |
| 17 | 9.4 | 6.2 | 1.05 | 5.1 | 6.2 | 11.4 | 7.5 | 1.25 | 6.2 | 7.5 | 827 | + 79 | +110 | — 5 | −16 |
| 9 | 6.3 | 4.1 | 0.7 | 3.4 | 4.1 | 7.3 | 4.7 | 0.8 | 3.9 | 4.7 | 869 | + 14 | + 33 | —41 | —27 |
| 8 | 4.9 | 3.1 | 0.5 | 2.6 | 3.1 | 5.6 | 3.6 | 0.55 | 3. | 3.6 | 875 | — 21 | — 8 | —55 | —44 |
| 6 | 6.7 | 4.3 | 0.75 | 3.5 | 4.3 | 8.1 | 5.2 | 0.9 | 4.2 | 5.2 | 836 | + 29 | + 51 | —34 | —2 |
| Ave. | 9.58 | 6.15 | 0.97 | 5.1 | 6.1 | 11.3 | 7.4 | 1.17 | 6.15 | 7.3 | 832 | + 67 | + 97 | — 7 | −13 |
| Standards: Haecker, Savage, modified | | | | | | | | | | | | | | | |
| Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards: Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |
| Following service | | | | | | | | | | | | | | | |
| 6 | 5.6 | 3.6 | 0.65 | 3. | 3.6 | 6.8 | 4.4 | 0.8 | 3.7 | 4.4 | 846 | + 14 | + 33 | —45 | —31 |
| 8 | 5.4 | 3.4 | 0.55 | 2.9 | 3.5 | 6.4 | 4. | 0.65 | 3.4 | 4.1 | 831 | — 7 | + 9 | —49 | —37 |
| 16 | 5.7 | 3.7 | 0.65 | 3. | 3.7 | 6.8 | 4.4 | 0.75 | 3.6 | 4.4 | 858 | + 7 | + 26 | —45 | —31 |

*Live weights not made.

*First period.* Jane ate during 14 weeks nearly or quite thrice as much digestible protein as and from ½ to ⅚ more total digestible nutrients than standards called for; yet, notwithstanding her large food intake, she barely held her own in respect to live weight, averaging to weigh just what she averaged during the last two months of lactation when she was receiving the same food intake.

*Second period.* She ate during 17 weeks from ⅘ excess to a little more than twice as much digestible protein as she needed, but barely enough total digestible nutrients, —1/20 to +⅙, and gained 4 percent in live weight. In other words, she did not gain in live weight when overfed and did gain when fed a considerably lessened ration supplying barely maintenance needs.

*Third period.* She ate during 9 weeks ⅐ to ⅓ excess of digestible protein, but her total digestible nutrient intake was from ¼ to ⅖ deficient; yet she gained 5 percent in live weight as compared with the average of the preceding period and 6 percent in live weight during the period.

*Fourth period.* She ate during 8 weeks from 1/12 to 1/5 less digestible protein and from 3/7 to 4/7 less total digestible nutrients than standards call for; yet she held her live weight on the whole, falling off slightly towards the close of the period.

*Fifth period.* She ate during 6 weeks from 3/10 to 1/2 excess of digestible protein but her total digestible nutrient intake was deficient by from 1/5 to 1/3; yet notwithstanding this increase in food intake, she lost 4 percent in live weight.

*Average.* She ate from 2/3 to twice as much digestible protein as she needed and not far from standard amounts of total digestible nutrients, —1/14 to +1/8; and gained 6 percent in live weight.

*Following service. Sixth period.* She ate during 6 weeks 1/7 to 1/3 excess digestible protein but her total digestible nutrient intake was deficient by 1/8 to 3/7. She gained 1 percent in live weight as compared with the average of the preceding period, but 4 percent during the course of the six weeks.

*Seventh period.* She ate during 8 weeks practically standard amounts of digestible protein for mere maintenance, —1/7 to +1/10 but from 3/8 to 1/2 too little total digestible nutrients and gained 2 percent in live weight.

*Eighth period.* She ate during 16 weeks from 1/14 to 1/4 excess of digestible protein but her total digestible nutrient intake was from 1/3 to 3/7 deficient for mere maintenance. Her ration closely resembled that furnished during the sixth period. She gained 3 percent in live weight as was to be expected.

Jane calved normally two months after the close of the eighth period, dropping an average sized and healthy Jersey calf. She gave during the succeeding year 7,424 pounds of milk and 403 pounds of fat and did laudable service in these trials for three more years.

II. 6. SABRA, grade Jersey, six years old, was fed the medium protein ration while dry and farrow for 426 days from July 12, 1908 to September 13, 1909. Her record as to food intake and live weights appears below. Her feeding record before and after service was as follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 3 | 18. | ... | .. | | | | |
| 17 | 11.6 | 0.7 | 4.4 | 17 | 3. | 7. | 2. |
| 17 | 5.3 | 10. | 3.6 | 11 | 3. | 7.6 | 1.8 |
| 8 | 3.6 | 7.2 | 3. | 19 | 4. | 8. | 2.6 |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| **Preceding service** | | | | | | | | | | | | | | | |
| 3 | 14.9 | 9. | 0.8 | 7.9 | 8.7 | 16.8 | 10.15 | 0.9 | 8.9 | 9.8 | 887 | +29 | + 51 | +26 | +54 |
| 17 | 14.5 | 9.2 | 1.2 | 7.8 | 9. | 16. | 10.1 | 1.3 | 8.6 | 9.9 | 907 | +86 | +118 | +26 | +54 |
| 17 | 11.1 | 7.2 | 0.9 | 6.1 | 7. | 11.5 | 7.5 | 0.95 | 6.3 | 7.3 | 965 | +36 | + 60 | — 7 | +14 |
| 8 | 8.1 | 5.3 | 0.75 | 4.6 | 5.35 | 8.2 | 5.4 | 0.75 | 4.7 | 5.4 | 985 | + 7 | + 26 | —32 | —1 |
| 17 | 6.5 | 4.2 | 0.5 | 3.6 | 4.1 | 6.9 | 4.5 | 0.55 | 3.8 | 4.4 | 941 | —21 | — 8 | —45 | —31 |
| **Ave.** | 10.75 | 6.9 | 0.85 | 5.95 | 6.85 | 11.4 | 7.3 | 0.91 | 6.3 | 7.25 | 945 | +30 | + 52 | — 9 | +11 |
| **Standards: Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey** | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| **Standards: Armsby, Eckles (converted)** | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |
| **Following service** | | | | | | | | | | | | | | | |
| 11 | 6. | 3.8 | 0.55 | 3.2 | 3.75 | 6.4 | 4. | 0.6 | 3.4 | 4. | 944 | —14 | + 1 | —50 | —3 |
| 19 | 7.6 | 4.9 | 0.7 | 4.1 | 4.8 | 8.2 | 5.3 | 0.75 | 4.4 | 5.2 | 933 | + 7 | + 26 | —34 | —1 |

*First period.* Sabra ate during 17 weeks from ⅞ to 7/6 excess of digestible protein and from ¼ to 4/7 too much total digestible nutrients. She maintained her live weight without material change during the first two-thirds of the period, then increased it very rapidly, gaining 9 percent over her initial weight.

*Second period.* She ate during 17 weeks ⅜ to ⅗ excess of digestible protein but from 1/14 too little to 1/7 too much total digestible nutrients. She dropped off a little in live weight at the outset but quickly regained what she lost and continued to increase in live weight until at the close of the period she weighed 6 percent more than the mean of the preceding period.

*Third period.* She ate during 8 weeks from 1/14 to ¼ more digestible protein but from ⅙ to ⅓ less total digestible nutrients than standards called for; and she maintained her live weight almost unchanged as compared with that of the previous 8 weeks, indeed, gaining 2 percent.

*Fourth period.* During 17 weeks her food intake was deficient 1/12 to 1/6 in digestible protein and 3/10 to 3/7 in total digestible nutrients; and she fell off rapidly in live weight, losing 3 percent during the first half and 2 percent more during the second half of the period, averaging a 5 percent loss as compared with the previous period.

*Average.* She ate from 3/10 to 1/2 more digestible protein than needed, but closely standard amounts of total digestible nutrients, —1/12 to +1/8; and she gained 4 percent in live weight.

*Following service. Fifth period.* She was fed during 11 weeks a diet which was lacking by from 0 to 1/7 in digestible protein and from 3/8 to 1/2 in total digestible nutrients for mere maintenance purposes. She gained in live weight at the outset but quickly lost the gains, being at low tide during the last month of the period.

*Sixth period.* She was then fed for 19 weeks a ration similar to that fed during the third period, carrying 1/14 to 1/4 excess of digestible protein and 1/5 to 1/3 deficiency in total digestible nutrients. Although advancing in gestation and, at the end of the period, three-fourths way on towards calving, she did not increase much in live weight; indeed she shrunk as compared with the former period, her average weights for successive six-week sub-periods being 920, 935, and 944 pounds. She aborted at eight months, weighing but 976 pounds. She remained in good health for four more years and was then sold.

The following table sets forth the general outcome for the six cows for which completed records are in hand as set forth on the preceding pages.

| No. | Name | Breed | Ration | Weeks fed | Digestible protein | Total digestible nutrients | Gain in live weight |
|---|---|---|---|---|---|---|---|
| II. 1. | Altje | Gd. Hol. | Med. | 57. | +29 to +50 | —18 to + 1 | 8 |
| 2. | Bontje | Gd. Hol. | Low | 68 | + 6 to +26 | — 7 to +13 | 11 |
| 3. | Durtje | Gd. Hol. | High | 58 | +40 to +65 | —24 to — 8 | 5 |
| 4. | Hazel K. | Gd. Jy. | Low | 69 | 0 to +18 | —16 to + 3 | 3 |
| 5. | Jane | Gd. Jy. | High | 54 | +67 to +97 | — 7 to +13 | 6 |
| 6. | Sabra | Gd. Jy. | Med. | 59 | +30 to +52 | — 9 to +11 | 4 |
|  | Average |  |  | 61 | +29 to +51 | —14 to + 6 | 6 |

What became of these cows? Was their future usefulness impaired by low feeding?

1. Altje. Aborted at six and one-half months; remained for five more years in good health and producing well.

2. Bontje: Calved normally; remained for four more years in good health and producing well.

3. Durtje: Calved normally; remained for two more years in good health and producing well; lost half her udder and was discarded.

4. Hazel K.: Calved normally; remained for five years in good health and producing well.

5. Jane: Calved normally; remained for three years in good health and producing well.

6. Sabra: Aborted at eight months; remained for four years in good health and producing well.

II. 7-20. The theft of the live weight record books, 1914 to 1917 (pp. 11-12), greatly curtailed the writer's opportunity to discuss the results secured during the study of maintenance *per se*. In no other section of the work reported upon in this bulletin was so great damage done; in fact in no other section was very serious damage done. The records made by 14 cows can only be used in the most general way. These cows were fed while dry and unserved for long periods of time, ranging from 537 to no less than 2,701 days. It should be said, however, that the scheme of the trial did not contemplate these very prolonged terms of feeding except in the case of Lanta; but the best laid plans of mice and men often go awry, and so in these cases. Barrenness was a most exasperating factor, serving to limit the work between 1914 and 1918. All the cows, except Lanta, were repeatedly served but to no avail.

Full records as to food uses are in hand for all the animals. The cows had been in use prior to or subsequent to—or both—the maintenance trials as such. Live weights had been taken twice or thrice weekly, extending in some cases over a long series of years, and these are in hand. Many wearisome hours were devoted to a most careful study of these weight records made prior to or subsequent to 1917. These data were gone over thrice independently. As a result of this careful study, hypothetical average live weight figures have been adopted for use in connection with the records of each of these 14 cows, the final result in each case being the average three computations of the same data made independently. Furthermore, in case a given result varied materially from the other two the data were again re-surveyed with a view of determining whether errors of computation had been made or faulty judgment had affected the result. It is the writer's opinion that in no case does a hypothetical average live weight figure vary materially from the real but unknown average live weight; that is to say, the actual average live weight for the entire duration of feeding treated as a unit. And there is this to be said, that no animal, except Lanta, passed out of the trials at their end in a seriously depleted condition. Of course some of the so-called "plungers" when at the nadir of their nutrient intakes were sorry looking individuals, but this was usually a temporary situation. Lanta, kept in the barn for 89 months dry and barren, toiled not neither did she spin, yet was gaunt and unthrifty at the close of her long confinement.

It would seem, therefore, that, notwithstanding the lamentable gap in the records made by the theft, the data possess considerable value, if for no other reason because of their volume. All this has been already said on page 12; but is now said again in order to state the facts in connection with this especially large usage of the impaired data.

The next table sets forth the names of these 14 cows, their ages at the time each entered upon this particular trial, the number of days during which they were fed, their hypothetical average live weights—secured as above indicated—the nature of the grain rations which were fed, their average nutrient intakes, actual and per 1,000 pounds live weight, and, finally, the increase or decrease as the case may be in the intakes of digestible proteins, carbohydrates and fat and total digestible nutrients as compared with standards, expressed as percentages.

II. 7-20. COWS, APPROXIMATE WEIGHTS, NUTRIENT INTAKE, ETC.

| Name | Breed (grades) | Age at beginning | Group number | Days fed | Approximate average live weight | Ration (protein content) | Daily consumption of digestible nutrients | | | | | Daily consumption of digestible nutrients per 1,000 pounds live weight | | | | | Comparison with standards ± | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients | H., S., etc. Digestible protein | A., E. Digestible protein | H., S., etc. Total digestible nutrients | A., E. Total digestible nutrients |
| | | | | | lbs. | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Dell R. | Ayrshire | 6 | I | 1,058 | 980 | High | 7.4 | 4.8 | 0.65 | 4.0 | 4.65 | 7.5 | 4.9 | 0.65 | 4.1 | 4.75 | — 7 | + 9 | —39 | —26 |
| Effa | Jersey | 7 | I | 1,001 | 830 | Low | 7.6 | 4.7 | 0.45 | 4.2 | 4.65 | 9.2 | 5.7 | 0.55 | 5.1 | 5.65 | —21 | — 8 | —28 | —13 |
| Evelyn | Holstein | 6½ | I | 1,462 | 1,060 | Low | 10.7 | 7.0 | 0.7 | 6.2 | 6.9 | 10.1 | 6.6 | 0.65 | 5.9 | 6.5 | — 7 | + 9 | —18 | + 1 |
| Lanta 2nd | (R.) Ayr. | 6 | I | 1,456 | 1,060 | Med. | 9.6 | 6.1 | 0.7 | 5.3 | 6.0 | 9.0 | 5.8 | 0.65 | 5.0 | 5.65 | — 7 | + 9 | —28 | —12 |
| Mary | Jersey | 6 | I | 1,062 | 1,040 | Med. | 9.3 | 6.0 | 0.75 | 5.2 | 5.95 | 9.0 | 5.8 | 0.75 | 5.0 | 5.75 | + 7 | + 26 | —27 | —11 |
| Nesbit | Jersey | 6 | I | 718 | 980 | High | 9.4 | 5.1 | 0.65 | 4.4 | 5.05 | 9.6 | 5.2 | 0.7 | 4.5 | 5.2 | 0 | + 18 | —34 | —20 |
| Augusta | Jersey | 10 | III | 935 | 820 | High | 9.8 | 6.4 | 0.95 | 5.4 | 6.35 | 12.0 | 7.8 | 1.15 | 6.6 | 7.75 | +64 | + 93 | — 2 | +20 |
| Fizzy | Jersey | 5 | II | 832 | 930 | High | 9.2 | 5.9 | 0.8 | 5.1 | 5.9 | 9.8 | 6.4 | 0.9 | 6.5 | 6.35 | +29 | + 51 | —19 | — 2 |
| Isadore | Jersey | 9 | III | 551 | 920 | Med. | 11.7 | 7.6 | 0.9 | 6.6 | 7.5 | 12.7 | 8.3 | 0.95 | 7.2 | 8.15 | +34 | + 60 | + 4 | +27 |
| Karah | Jersey | 6 | I | 805 | 890 | Low | 8.9 | 5.6 | 0.5 | 5.0 | 5.5 | 9.8 | 6.3 | 0.6 | 5.7 | 6.3 | —14 | + 1 | —21 | — 3 |
| Vinegar | Jersey | 6 | II | 559 | 910 | Med. | 9.5 | 6.1 | 0.75 | 5.3 | 6.05 | 10.5 | 6.7 | 0.8 | 5.8 | 6.6 | +14 | + 34 | —16 | + 2 |
| Hepsy | Jersey | 9 | IV | 567 | 950 | High | 15.8 | 10.3 | 1.3 | 8.9 | 10.2 | 16.6 | 10.8 | 1.35 | 9.4 | 10.75 | +93 | +127 | +36 | +66 |
| Mab | Jersey | 10 | IV | 537 | 900 | Med. | 15.9 | 10.2 | 1.15 | 9.0 | 10.15 | 17.7 | 11.4 | 1.25 | 10.0 | 11.25 | +78 | +110 | +42 | +74 |
| Lanta | (R.) Ayr. | 7 | I | 2,701 | 900 | Low | 9.2 | 5.8 | 0.6 | 5.2 | 5.8 | 10.2 | 6.5 | 0.65 | 5.8 | 6.45 | — 7 | + 9 | —18 | 0 |
| Average | | | | 1,017 | 941 | | 10.3 | 6.55 | 0.78 | 5.7 | 6.5 | 11.0 | 7.0 | 0.83 | 6.1 | 6.95 | +18 | + 39 | —12 | + 6 |
| Standards: Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | | | | | | | 0.7 | | 7.93 | | | | |
| Standards: Armsby, Eckles (converted) | | | | | | | | | | | | | | 0.595 | | 6.48 | | | | |

These 14 records seem to fall naturally into four groups of 8, 2, 2, and 2.

I. Dell R., Effa, Evelyn, Lanta 2nd, Mary, Nesbit, Karah and Lanta were underfed. They ate rations which in respect to digestible protein ranged from ¼ excess to ⅕ deficiency and in respect to total digestible nutrients from 0 to ⅖ deficiency.

II. Fizzy and Vinegar ate from ⅐ to ½ more digestible protein than seemed necessary but from 0 to ⅕ less total digestible nutrients.

III. Augusta and Isadore ate from ⅓ to 9/10 more digestible protein and from 0 to ¼ more total digestible nutrients than seemed necessary.

IV. Hepsy and Mab were greatly overfed, consuming from ⅘ to 5/4 excess of digestible protein and from ⅜ to ¾ excess of total digestible nutrients.

In the next table an attempt is made to segregate the periods of diverse feeding of 10 of these cows. Evelyn, Mary, Lanta and Lanta 2nd were intentionally fed in very variable fashion, sometimes greatly overfed, sometimes almost cruelly underfed, so that these records can not be thus calculated. These four cows constituted the so-called "plungers." The average amounts of hay, silage—sometimes soiling crops or apple pomace in part replaced silage—and grain fed per week, and the average daily intake in terms of total dry matter, digestible dry matter, digestible protein, digestible carbohydrates and fat and total digestible nutrients, are stated. It will be observed that while fluctuations in feeding occurred, which doubtless were reflected in varying live weights, the trend in group I was considerably to underfeed, in group II somewhat to underfeed, in group III to somewhat to overfeed and in group IV greatly to overfeed.

II. 7 TO 20. WEEK'S RATIONS; DAILY NUTRIENT INTAKES

| Weeks fed | Week's ration | | | Digestible nutrients—daily consumption | | | | | Weeks fed | Week's ration | | | Digestible nutrients—daily consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients | | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Group I. Cows which on the whole were underfed | | | | | | | | | | | | | | | | | |
| Dell R. High protein grain ration (151 weeks) | | | | | | | | | Effa. Low protein grain ration (143 weeks) | | | | | | | | |
| 2 | 51 | 148 | 18. | 13.9 | 8.9 | 1.1 | 7.6 | 8.7 | 3 | 87 | 42 | 30. | 15.9 | 10.0 | 1.1 | 8.7 | 9.8 |
| 8 | 31 | 68 | 19. | 8.3 | 5.5 | 0.9 | 4.5 | 5.4 | 5 | 39 | 78 | 23. | 10.2 | 6.5 | 0.7 | 5.8 | 6.5 |
| 18 | 16 | 43 | 9.3 | 4.5 | 2.9 | 0.45 | 2.5 | 3.0 | 60 | 23 | 47 | 14.2 | 6.2 | 4.0 | 0.4 | 3.6 | 4.0 |
| 12 | 26 | 54 | 18.7 | 7.3 | 4.8 | 0.85 | 3.9 | 4.8 | 65 | 29 | 55 | 16.8 | 7.6 | 4.9 | 0.45 | 4.4 | 4.9 |
| 11 | 35 | 80 | 23. | 10.0 | 6.5 | 1.1 | 5.4 | 6.5 | 10 | 34 | 69 | 20.5 | 8.9 | 5.7 | 0.55 | 5.1 | 5.7 |
| 55 | 24 | 50 | 14. | 6.5 | 4.3 | 0.75 | 3.6 | 4.4 | | | | | | | | | |
| 10 | 49 | 99 | 29.2 | 13.3 | 8.6 | 1.2 | 7.4 | 8.6 | | | | | | | | | |
| 18 | 25 | 53 | 15.4 | 6.7 | 4.3 | 0.55 | 3.6 | 4.2 | | | | | | | | | |
| 4 | 56 | 112 | 33.6 | 14.7 | 9.6 | 1.45 | 7.9 | 9.4 | | | | | | | | | |
| 13 | 22 | 51 | 14.4 | 5.9 | 3.9 | 0.5 | 3.2 | 3.7 | | | | | | | | | |
| Karah. Low protein grain ration (115 weeks) | | | | | | | | | Nesbit. High protein grain ration (103 weeks) | | | | | | | | |
| 17 | 63 | 126 | 0. | 12.3 | 7.6 | 0.4 | 7.0 | 7.4 | 3 | 41 | 100 | 6.6 | 8.7 | 5.5 | 0.55 | 4.9 | 5.4 |
| 5 | 63 | 126 | 28. | 15.8 | 10.1 | 0.65 | 9.3 | 10.0 | 38 | 39 | 80 | 2.8 | 7.6 | 4.7 | 0.4 | 4.2 | 4.6 |
| 5 | 39 | 79 | 23.3 | 10.6 | 6.8 | 0.6 | 6.2 | 6.8 | 7 | 44 | 112 | 5.5 | 9.7 | 6.0 | 0.6 | 5.3 | 5.9 |
| 41 | 24 | 52 | 15.3 | 6.4 | 4.1 | 0.4 | 3.7 | 4.1 | 7 | 38 | 80 | 23. | 10.2 | 6.6 | 1.1 | 5.5 | 6.6 |
| 7 | 42 | 84 | 25.2 | 10.7 | 6.9 | 0.7 | 6.1 | 6.8 | 4 | 25 | 60 | 16.1 | 7.0 | 4.6 | 0.75 | 3.8 | 4 6 |
| 16 | 25 | 53 | 16. | 6.7 | 4.2 | 0.4 | 3.8 | 4.2 | 17 | 18 | 43 | 9.2 | 4.8 | 3.1 | 0.45 | 2.6 | 3.1 |
| 24 | 39 | 77 | 23.3 | 9.9 | 6.4 | 0.6 | 5.8 | 6.4 | 6 | 23 | 51 | 15.2 | 6.4 | 4.2 | 0.7 | 3.5 | 4.2 |
| | | | | | | | | | 21 | 38 | 75 | 22.8 | 10.1 | 6.6 | 1.1 | 5.4 | 6.5 |

Evelyn, Mary, Lanta and Lanta 2nd were intentionally fed in variable fashion. Their records can not be thus stated to advantage.

II. 7 TO 20. WEEK'S RATIONS; DAILY NUTRIENT INTAKES—*continued*

| Weeks fed | Week's ration | | | Digestible nutrients—daily consumption | | | | | Weeks fed | Week's ration | | | Digestible nutrients—daily consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients | | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Group II. Cows eating more protein but less carbohydrates and fat than standards indicate | | | | | | | | | | | | | | | | | |
| Fizzy. High protein grain ration (120 weeks) | | | | | | | | | Vinegar. Medium protein grain ration (80 weeks) | | | | | | | | |
| 13 | 49 | 105 | 0. | 9.9 | 6.1 | 0.35 | 5.5 | 5.9 | 15 | 49 | 98 | 14. | 11.3 | 7.2 | 0.65 | 6.4 | 7.1 |
| 15 | 51 | 106 | 23.5 | 13.0 | 8.4 | 0.85 | 7.3 | 8.2 | 2 | 49 | 98 | 29.4 | 13.3 | 8.5 | 0.95 | 7.5 | 8.5 |
| 4 | 42 | 82 | 25.5 | 11.3 | 7.3 | 1.0 | 6.3 | 7.3 | 1 | 61 | 125 | 35.5 | 16.2 | 10.4 | 1.2 | 9.2 | 10.4 |
| 26 | 26 | 55 | 16.1 | 7.0 | 4.5 | 0.7 | 3.8 | 4.5 | 4 | 77 | 154 | 44.8 | 20.6 | 13.3 | 1.5 | 11.7 | 13.2 |
| 13 | 45 | 89 | 26.5 | 11.4 | 7.4 | 1.15 | 6.2 | 7.4 | 3 | 59 | 118 | 34.8 | 15.9 | 10.2 | 1.15 | 9.0 | 10.2 |
| 27 | 28 | 56 | 16.8 | 7.2 | 4.8 | 0.7 | 3.9 | 4.6 | 9 | 42 | 84 | 25.2 | 11.4 | 7.3 | 0.85 | 6.4 | 7.3 |
| 22 | 35 | 70 | 21. | 8.9 | 5.8 | 0.85 | 4.9 | 5.8 | 44 | 28 | 56 | 16.8 | 7.2 | 4.7 | 0.6 | 4.0 | 4.6 |
| | | | | | | | | | 2 | 21 | 49 | 14. | 5.9 | 3.8 | 0.5 | 3.2 | 3.7 |
| Group III. Cows eating much more protein than standards indicate and standard amounts of carbohydrates and fat | | | | | | | | | | | | | | | | | |
| Augusta. High protein grain ration (134 weeks) | | | | | | | | | Isadore. Medium protein grain ration (79 weeks) | | | | | | | | |
| 13 | 42 | 84 | 11.2 | 9.6 | 6.1 | 0.6 | 5.4 | 6.0 | 10 | 70 | 147 | 0 | 13.9 | 8.5 | 0.6 | 7.8 | 8.4 |
| 2 | 55 | 110 | 31.6 | 14.7 | 9.6 | 1.25 | 8.2 | 9.5 | 4 | 70 | 147 | 28. | 17.4 | 11.1 | 1.1 | 9.9 | 11.0 |
| 5 | 70 | 147 | 42. | 19.2 | 12.5 | 1.8 | 10.8 | 12.6 | 4 | 84 | 168 | 49. | 21.4 | 13.8 | 1.75 | 11.9 | 13.7 |
| 10 | 49 | 98 | 28.8 | 13.2 | 8.6 | 1.15 | 7.4 | 8.6 | 7 | 70 | 141 | 38.3 | 17.7 | 11.4 | 1.4 | 9.9 | 11.3 |
| 6 | 32 | 64 | 21. | 8.6 | 5.6 | 0.85 | 4.7 | 5.6 | 6 | 51 | 102 | 30.8 | 13.9 | 9.0 | 1.15 | 7.7 | 8.9 |
| 28 | 28 | 56 | 16.8 | 7.4 | 4.8 | 0.7 | 4.0 | 4.7 | 22 | 28 | 56 | 16.8 | 7.3 | 4.7 | 0.6 | 4.1 | 4.7 |
| 23 | 42 | 84 | 25.2 | 10.7 | 7.0 | 1.1 | 5.8 | 6.9 | 26 | 42 | 84 | 25.2 | 11.0 | 7.0 | 0.9 | 6.2 | 7.1 |
| 29 | 28 | 57 | 17. | 7.2 | 4.7 | 0.7 | 4.1 | 4.8 | | | | | | | | | |
| 18 | 42 | 84 | 23.8 | 10.7 | 6.9 | 1.1 | 5.7 | 6.9 | | | | | | | | | |

II. 7 TO 20. WEEK'S RATIONS; DAILY NUTRIENT INTAKES—*concluded*

| Weeks fed | Week's ration | | | Digestible nutrients—daily consumption | | | | | Weeks fed | Week's ration | | | Digestible nutrients—daily consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients | | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat (× 2¼) | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Group IV. Cows which were greatly overfed | | | | | | | | | | | | | | | | | |
| Hepsy. High protein grain ration (81 weeks) | | | | | | | | | Mab. Medium protein grain ration (77 weeks) | | | | | | | | |
| 3 | 56 | 280 | 0. | 17.3 | 10.8 | 0.65 | 9.5 | 10.2 | 4 | 56 | 252 | 0. | 16.3 | 10.1 | 0.6 | 9.0 | 9.6 |
| 2 | 56 | 140 | 17.5 | 14.8 | 9.4 | 1.1 | 8.0 | 9.1 | 2 | 56 | 140 | 17. | 14.2 | 9.0 | 0.8 | 7.9 | 8.7 |
| 6 | 60 | 132 | 35.2 | 17.3 | 11.2 | 1.6 | 9.3 | 10.9 | 6 | 57 | 135 | 31. | 15.9 | 10.2 | 1.1 | 8.9 | 10.0 |
| 11 | 96 | 188 | 50. | 25.2 | 16.3 | 2.25 | 13.6 | 15.9 | 31 | 84 | 147 | 49.1 | 21.9 | 14.1 | 1.6 | 12.3 | 13.9 |
| 35 | 66 | 136 | 47.7 | 19.0 | 12.5 | 1.8 | 10.5 | 12.3 | 6 | 54 | 177 | 53.2 | 19.6 | 12.8 | 1.6 | 11.2 | 12.8 |
| 5 | 49 | 95 | 28.5 | 12.6 | 8.2 | 1.2 | 6.8 | 8.0 | 9 | 45 | 90 | 26.8 | 11.7 | 7.4 | 0.95 | 6.6 | 7.6 |
| 8 | 28 | 56 | 16.8 | 7.3 | 4.8 | 0.7 | 4.0 | 4.7 | 19 | 28 | 56 | 16.8 | 7.3 | 4.6 | 0.6 | 4.0 | 4.6 |
| 6 | 14 | 28 | 8.4 | 3.7 | 2.4 | 0.35 | 2.0 | 2.4 | | | | | | | | | |
| 5 | 14 | 28 | ... | 2.6 | 1.6 | 0.1 | 1.4 | 1.5 | | | | | | | | | |

The following table sets forth the salient features of the results secured with these four groups:

| | | | Fed on the average for | Comparison with standards | |
|---|---|---|---|---|---|
| | | | | Digestible protein | Total digestible nutrients |
| | | | | % % | % % |
| I. | Underfed ....... | 8 cows | 42 mos. | — 7 to + 9 | —11 to —27 |
| II. | Underfed ....... | 2 cows | 23 mos. | +22 to + 43 | 0 to —18 |
| III. | Well fed ....... | 2 cows | 24½ mos. | +49 to + 77 | + 1 to +24 |
| IV. | Greatly overfed.. | 2 cows | 18 mos. | +86 to +119 | +39 to +70 |

What happened to these cows following their long periods of service in these maintenance trials?

*Group I. Considerably underfed. Dell R.* Dry for three years, barren, otherwise in good condition, withdrawn. *Effa.* Dry for nearly three years, barren, otherwise in good condition, withdrawn. *Evelyn.* Dry for over four years, barren, otherwise in good condition, withdrawn. *Lanta 2nd.* Dry over four years, barren, otherwise in good condition, withdrawn. *Mary.* Dry over three years, barren, otherwise in good condition, withdrawn. *Nesbit.* Dry two years, served, conceived, aborted at eight months, in somewhat poor condition (1921). *Karah.* Dry two and a half years, served, conceived, calved normally, now (1921) in good condition. *Lanta.* Designedly kept dry, unserved for nearly seven and a half years.

*Group II. Somewhat underfed. Fizzy.* Dry for more than two years, died (accident). *Vinegar.* Dry one and a half years, off feed, sick, died.

*Group III. Somewhat overfed. Augusta.* Dry for two and a half years, served, conceived, aborted at eight and a half months, sold. *Isadore.* Dry one and a half years, served, conceived, aborted at 6 months; now (1921) in good condition.

*Group IV. Greatly overfed. Hepsy.* Dry one and a half years, barren, sold. *Mab.* Dry, one and a half years, barren, sold.

Summing up the outcome and referring to the preceding tables, setting forth the condensed and salient features of the results secured with the six cows for which we have complete records and the 14 whose records are rendered faulty because of the theft, we may say:

*A. Concerning the complete records:*

1. *Length of feeding.* These six cows were fed for from 13 to 16 months, averaging 14 months.

2. *Variation in rations.* Their rations varied, some cows eating more than others. Furthermore the same cow at different times received rations differing more or less as to their food contents but not

as to the materials fed, except that the quality of the hay fed necessarily was somewhat changeable from season to season and that silage sometimes was not fed during the summer months.

3. *Digestible protein intake.* Every cow on the average ate standard or super-standard—usually the latter—amounts of digestible protein, averaging $\frac{3}{10}$ to $\frac{1}{2}$ excess.

4. *Total digestible nutrient intake.* Three cows on the average, according to the lower standards, ate $\frac{1}{8}$ excess but, according to the higher standards, $\frac{1}{13}$ deficiency; two ate standards amounts according to one and $\frac{1}{6}$ sub-standard amounts according to the other; and one ate sub-standard amounts ($-\frac{1}{4}$ and $-\frac{1}{12}$) by both the lower and the higher standards. The average record is $\frac{1}{8}$ deficiency to $\frac{1}{20}$ excess.

5. *Gain in live weight.* Every cow gained in live weight, the gains ranging from 3 to 11 percents; and this notwithstanding the fact that the feeding was on the whole sub-standard in respect to total digestible nutrients ($-\frac{1}{14}$ to $-\frac{1}{4}$ by the higher, $+\frac{1}{8}$ to $\frac{1}{12}$ by the lower standards). All the cows were mature and the gains in live weight are not to be ascribed to advancing years.

6. *Continued wellbeing of the cows.* Two of the six cows aborted, but there seems no necessary causal relationship to be ascribed to their feeding. Every cow remaining in good health and doing good service for a series of years, ranging from two to five.

*B. Concerning the incomplete records.*

*Group I. Considerably underfed for three and a half years.*

About all that can be said under the circumstances as to these eight cows in Group I is that two to four years of decided underfeeding—the shortages of total digestible nutrients, as judged by standards, amounting to from 0 to $\frac{2}{5}$—did not seem to result in permanent injury to any cow. Indeed, they seem to have done quite as well as those fed more liberally, being none the worse for their long continued food shortage.

*Group II. Somewhat underfed for two years.*

These two cows seem to have gotten along pretty well after their two years' short rationing (0 to $\frac{1}{5}$ total digestible nutrients). To be sure both died within two years after the close of the period, but there does not appear to be any necessary or probable relationship between these mishaps and their insufficient feeding.

*Group III. Well fed for two years.*

Both of these cows aborted but their appears no necessary relation between this fact and their feeding (0 to $+\frac{1}{4}$ total digestible nutrients).

*Group IV. Decidedly overfed for one and a half years.*

These two overfed cows (+⅜ to +¾ total digestible nutrients) later on proved barren and were sold.

In view of the volume of the data presented in this particular phase of the trials, the extreme length of the feeding periods, the fact that at least no serious damage to bovine wellbeing seems to have resulted and that their ability to do good work subsequent to the close of the maintenance period does not seem to have been impaired, is it not fair to raise the question whether the amount of nutrients heretofore set forth in the form of standards as necessary for the maintenance of dry dairy cows is not excessive; whether such cows may not be maintained on a considerably smaller food intake? The writer, at any rate, is quite convinced that the Haecker, Savage, modified Wolff-Lehmann and Woll-Humphrey standards for bovine maintenance are decided overstatements and that the Armsby and Eckles (converted) standards are in no respect understatements, that if anything they err on the side of liberality. However, in spite of the great volume of data presented herewith and the quite definite results secured, he is not inclined to suggest any lower figures than those proposed by Armsby and Eckles.

## III AND IV. MAINTENANCE AND FŒTAL CONSTRUCTION

### III. NORMAL PARTURITION

Six cows carried their calves to full time, one of them twice. Seven records are available but one (III. 6) is vitiated by the loss of the weight data. In six instances the cows had been dry for from 6 to 26 months prior to service, in one instance service was practically coincident with drying off. With one exception the cows were decidedly underfed, judged by mere maintenance standards.

The statements as to feeds, food intakes and live weights follow. The relation of the food intakes to mere maintenance needs—regardless of the draft of fœtal construction—appears at the right of each table. The tables are massed together in the discussion of this plan of the work dealing specifically with the relation of the food intake to fœtal construction.

III. 1. BONTJE, grade Holstein, 11 years old, served July 15, 1911, calved April 15, 1912, at 275 days was fed the low protein ration. Her feeding before and after service was very slightly varied, being essentially as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 41 | 5.2 | 12.5 | 2.5 | 9 | 8. | 12.5 | 3. |
| 5 | 4. | 12.5 | 3. | 25 | 8. | 12.5 | 2.8 |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E. | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 41 | 10.2 | 6.5 | 0.7 | 5.7 | 6.4 | 8.4 | 5.4 | 0.55 | 4.7 | 5.3 | 1,202 | —23 | — 8 | —33 | —18 |
| Succeeding service | | | | | | | | | | | | | | | |
| 5 | 9. | 5.9 | 0.6 | 5.3 | 5.9 | 7.6 | 5. | 0.5 | 4.5 | 5. | 1,192 | —29 | —16 | —37 | —23 |
| 9 | 12.2 | 7.8 | 0.75 | 7. | 7.7 | 10. | 6.4 | 0.6 | 5.7 | 6.3 | 1,220 | —14 | + 1 | —20 | — 2 |
| 25 | 12. | 7.6 | 0.75 | 6.7 | 7.5 | 9.45 | 6. | 0.6 | 5.3 | 5.9 | 1,268 | —14 | + 1 | —25 | — 8 |
| Ave. | 11.65 | 7.45 | 0.73 | 6.6 | 7.35 | 9.35 | 6. | 0.59 | 5.3 | 5.9 | 1,246 | —15 | — 1 | —25 | — 8 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week periods following service, 1,192, 1,215, 1,225, 1,224, 1,249, 1,275, 1,285, 1,298 pounds. Average weight after calving, 1,175 pounds. Approximate weights: calf 85 pounds, placenta, etc. 30 pounds.

III. 2. DURTJE, grade Holstein, eight years old, served January 15, 1910, calved October 20, 1910, at 279 days was fed the high protein ration. Her feeding before and after service was somewhat varied as appears below:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 33 | 5.2 | 10.8 | 2.7 | 9 | 6. | 14.4 | 4. |
| 14 | 5. | 11.3 | 2.8 | 13 | 8. | 17.7 | 5. |
| 4 | 6. | 12.5 | 3. | | | | |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E. | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 33 | 10. | 6.4 | 1.05 | 5.3 | 6.3 | 8. | 5.1 | 0.85 | 4.2 | 5.05 | 1,248 | +21 | + 42 | —36 | —22 |
| Succeeding service | | | | | | | | | | | | | | | |
| 14 | 9.6 | 6.2 | 1. | 5.1 | 6.1 | 7.6 | 4.9 | 0.8 | 4. | 4.8 | 1,263 | +14 | + 33 | —39 | —25 |
| 4 | 11.5 | 7.4 | 1.15 | 6.2 | 7.35 | 9. | 5.8 | 0.9 | 4.8 | 5.7 | 1,284 | +29 | + 50 | —28 | —12 |
| 9 | 13.1 | 8.6 | 1.35 | 7.1 | 8.45 | 9.9 | 6.5 | 1. | 5.3 | 6.4 | 1,328 | +43 | + 67 | —19 | — 1 |
| 13 | 15.9 | 10.4 | 1.75 | 8.6 | 10.35 | 11.4 | 7.4 | 1.25 | 6.1 | 7.4 | 1,399 | +79 | +108 | — 7 | +14 |
| Ave. | 12.7 | 8.3 | 1.33 | 6.8 | 8.2 | 9.55 | 6.2 | 1. | 5.1 | 6.1 | 1,325 | +43 | + 67 | —23 | — 5 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week periods, 1,270, 1,257, 1,261, 1,286, 1,352, 1,340, 1,386, 1,435 pounds. Average weight after calving, 1,318 pounds. Approximate weights: calf 85 pounds, placenta, etc. 30 pounds.

III. 3. HAZEL K., grade Jersey, six years old was served November 28, 1909, calved August 31, 1910, at 276 days. She was fed the low protein ration. Her feeding before and after service was reasonably uniform as appears below:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 8 | 3.4 | 6.2 | 3.1 | 21 | 5. | 10. | 2.8 |
| 11 | 3. | 5. | 2. | 19 | 5. | 12.5 | 3. |
| 16 | 4. | 8. | 2.3 | | | | |

Her nutrient intake and comparison data follow:

| Weeks | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| **Preceding service** | | | | | | | | | | | | | | | |
| 8 | 8. | 5.2 | 0.55 | 4.6 | 5.15 | 7.6 | 5. | 0.5 | 4.4 | 4.9 | 1,050 | —29 | —17 | —38 | —25 |
| 11 | 6. | 3.9 | 0.45 | 3.4 | 3.85 | 6. | 3.9 | 0.45 | 3.4 | 3.85 | 1,004 | —34 | —25 | —51 | —41 |
| 16 | 8. | 5.1 | 0.6 | 4.5 | 5.1 | 8.1 | 5.2 | 0.6 | 4.5 | 5.1 | 990 | —14 | 0 | —35 | —22 |
| **Succeeding service** | | | | | | | | | | | | | | | |
| 21 | 9.1 | 5.8 | 0.6 | 5.2 | 5.8 | 9.1 | 5.8 | 0.6 | 5.2 | 5.8 | 1,004 | —14 | 0 | —27 | —11 |
| 19 | 10.7 | 6.9 | 0.7 | 6.1 | 6.8 | 9.8 | 6.4 | 0.65 | 5.6 | 6.3 | 1,085 | — 7 | + 8 | —20 | — 2 |
| Ave. | 9.9 | 6.35 | 0.65 | 5.65 | 6.3 | 9.45 | 6.1 | 0.62 | 5.4 | 6.05 | 1,044 | —11 | + 3 | —23 | — 6 |
| **Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey** | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| **Standards (maintenance): Armsby, Eckles (converted)** | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week periods, 991, 1,000, 1,004, 1,016, 1,052, 1,079, 1,096, 1,104 pounds. Average weight after calving, 1,005 pounds. Approximate weights: calf 75 pounds, placenta, etc. 25 pounds.

III. 4. JANE, grade Jersey, six years old, served September 7, 1909, calved June 15, 1910, at 281 days was fed the high protein ration. Her feeding prior to and subsequent to service was quite uniform until the last quarter of her gestation, as appears below:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 9 | 3.3 | 5.4 | 1.9 | 5 | 3. | 6. | 1.9 |
| 8 | 2.4 | 5. | 1.3 | 8 | 3. | 7.3 | 1.4 |
| 6 | 3.7 | 6. | 2. | 16 | 3. | 6. | 1.9 |
| | | | | 11 | 4.6 | 9.7 | 2.9 |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | nutrients Total digestible | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 9 | 6.3 | 4.1 | 0.7 | 3.4 | 4.1 | 7.3 | 4.7 | 0.8 | 3.9 | 4.7 | 860 | +14 | +34 | —41 | —27 |
| 8 | 4.9 | 3.1 | 0.5 | 2.6 | 3.1 | 5.6 | 3.6 | 0.55 | 3. | 3.6 | 875 | —21 | — 8 | —55 | —44 |
| 6 | 6.7 | 4.3 | 0.75 | 3.5 | 4.3 | 8.1 | 5.2 | 0.9 | 4.2 | 5.2 | 836 | +29 | +51 | —34 | —20 |
| Succeeding service | | | | | | | | | | | | | | | |
| 5 | 5.6 | 3.65 | 0.7 | 3. | 3.6 | 6.6 | 4.3 | 0.85 | 3.6 | 4.3 | 846 | +22 | +43 | —46 | —34 |
| 8 | 5.4 | 3.4 | 0.55 | 2.9 | 3.5 | 6.5 | 4.1 | 0.65 | 3.5 | 4.25 | 831 | — 7 | +10 | —47 | —35 |
| 16 | 5.6 | 3.7 | 0.65 | 3. | 3.7 | 6.5 | 4.3 | 0.75 | 3.5 | 4.3 | 858 | + 7 | +26 | —46 | —34 |
| 11 | 8.7 | 5.8 | 1. | 4.7 | 5.7 | 9.7 | 6.4 | 1.1 | 5.2 | 6.3 | 901 | +57 | +85 | —21 | — 3 |
| Ave. | 6.4 | 4.2 | 0.73 | 3.45 | 4.2 | 7.4 | 4.85 | 0.8 | 4. | 4.85 | 863 | +20 | +41 | —39 | —26 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week periods, 840, 845, 824, 842, 858, 872, 893, 910 pounds. Average weight after calving, 823 pounds. Approximate weights: calf 55 pounds, placenta, etc. 25 pounds.

III. 5. KARAH, grade Jersey, eight years, was served August 4, 1918 and calved May 16, 1919, her gestation period being 284 days. She was fed the low protein ration. Her feeding preceding and subsequent to service was as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 24 | 5.6 | 11. | 3.3 | 3 | 3. | 5.8 | 1.7 |
| 4 | 2. | 4.2 | 1.4 | 34 | 4. | 8. | 2.4 |

Her food intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | .lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 24 | 9.9 | 6.4 | 0.6 | 5.8 | 6.4 | .. | .. | .. | .. | .. | * | .... | .... | .... | .... |
| Succeeding service | | | | | | | | | | | | | | | |
| 4 | 3.8 | 2.4 | 0.25 | 2.1 | 2.4 | 4.6 | 2.9 | 0.3 | 2.6 | 2.9 | 820 | —57 | —50 | —63 | —55 |
| 3 | 5.2 | 3.3 | 0.35 | 2.9 | 3.3 | 6.3 | 4. | 0.45 | 3.5 | 4. | 820 | —37 | —25 | —49 | —38 |
| 34 | 7.3 | 4.7 | 0.5 | 4.1 | 4.6 | 8.8 | 5.7 | 0.6 | 4.9 | 5.5 | 837 | —14 | + 1 | —30 | —14 |
| Ave. | 6.8 | 4.4 | 0.47 | 3.8 | 4.3 | 8.15 | 5.35 | 0.56 | 4.6 | 5.15 | 834 | —20 | — 6 | —35 | —21 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

*Live weights unavailable (pages 11-12).

Average weights in successive five-week periods, ——, ——, 816, 826, 826, 826, 835, 845 pounds. Average weight after calving, 789 pounds. Approximate weights: calf 40 pounds, placenta, etc. 15 pounds.

III. 6. NESBIT, grade Jersey, 10 years old, was served June 27, 1917 and calved April 10, 1918, at 287 days. She was fed the high protein ration. Her weight records are missing (see pages 11-12). Her food and nutrient intakes were as follows:

| Weeks | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients |
|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 15 | 6. | 12. | 3.6 | 11. | 7.25 | 1.1 | 6.05 | 7.15 |
| 8 | 4. | 8. | 2.4 | 7.35 | 4.85 | 0.75 | 4.05 | 4.8 |
| 5 | 3. | 7. | 2.2 | 6.1 | 4. | 0.6 | 3.35 | 3.95 |
| $12\frac{3}{7}$ | 6. | 12. | 3.6 | 11. | 7.25 | 1.1 | 6.05 | 7.15 |
| Ave. | 5.2 | 10.5 | 3.1 | 9.7 | 6.4 | 0.95 | 5.3 | 6.3 |

Her average weight, exclusive of that of the growing fœtus, was probably not far from 950 pounds. On that assumption, she ate always more digestible protein than standard indicated, sub- or super-standard amounts of total digestible nutrients during the first and last third of gestation and decidedly sub-standard amounts during the middle third, the figures being: digestible protein, +½ to +⅘ and —1/10 to +1/10 for the two ends and the middle; total digestible nutrients —1/10 and +1/10 and —¼ to —½ for the two ends and the middle. On the average the cow doubtless ate an excess of digestible protein and from 0 to ⅕ deficiency of total digestible nutrients. In this comparison, however, no account has been taken of the draft of the growing fœtus upon the food supply. Nesbit calved normally, dropping a healthy calf.

III. 7. NESBIT, grade Jersey, 11 years old, served September 24, 1918, calved July 1, 1919, at 279 days. She was fed the high protein ration. Her ration, following service, was excessive[1] and varied considerably. She made 129 pounds of milk following service.

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[1] It should be said, concerning Nesbit, that she proved to be an abnormal and very inferior cow. Unless liberally fed, indeed grossly overfed, she did not maintain live weight. When in milk and thus overfed she neither yielded well nor gained materially in live weight. She was a feminine bovine Jonah. Her records are included, so far as printing goes, but possibly should be excluded in final summations.

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 8 | 11.6 | 23.1 | 6.8 | 4 | 14. | 28. | 8. |
| 14 | 10. | 22. | 6. | 7 | 11.3 | 24. | 7. |
| 2 | 11.3 | 22.2 | 6.5 | 5 | 10. | 17.3 | 6. |

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E. | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Succeeding service | | | | | | | | | | | | | | | |
| 8 | 21.5 | 14. | 2.2 | 11.5 | 13.7 | 21.5 | 14. | 2.2 | 11.5 | 13.7 | 1,001 | +214 | +270 | +75 | +114 |
| 14 | 18.4 | 12. | 1.9 | 9.9 | 11.8 | 18.6 | 12.1 | 1.9 | 10. | 11.9 | 990 | +171 | +219 | +50 | + 85 |
| 2 | 20.5 | 13.4 | 2.1 | 11. | 13.1 | 19.7 | 12.9 | 2. | 10.6 | 12.6 | 1,035 | +186 | +236 | +61 | + 97 |
| 4 | 25. | 16.2 | 2.5 | 13.4 | 15.9 | 22.2 | 14.7 | 2.3 | 12.2 | 14.5 | 1,100 | +229 | +287 | +84 | +125 |
| 7 | 21.5 | 14. | 2.2 | 11.5 | 13.7 | 18.7 | 12.2 | 1.9 | 10. | 11.9 | 1,147 | +171 | +219 | +50 | + 85 |
| 5 | 17.9 | 11.6 | 1.8 | 9.6 | 11.4 | 15.3 | 9.9 | 1.55 | 8.2 | 9.7 | 1,170 | +121 | +161 | +24 | + 50 |
| Ave. | 20.2 | 13.1 | 2.1 | 10.8 | 12.9 | 19.1 | 12.4 | 2. | 10.2 | 12.2 | 1,057 | +186 | +236 | +55 | + 90 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week periods, 997, 998, 996, 1,020, 1,000, 1,117, 1,153, 1,170 pounds. Average weight after calving, 1,000 pounds. Approximate weights: calf 120 pounds, placenta, etc. 50 pounds.

The following table sets forth the essential situation in each case (except III. 6), in so far as it relates to comparison with food needs for mere maintenance regardless of the draft that fœtal contruction may make upon the nutrient intake.

| | H. & S. Digestible protein | A. & E. Digestible protein | H. & S. Total digestible nutrients | A. & E. Total digestible nutrients | Live weight |
|---|---|---|---|---|---|
| Bontje | — 15 | — 1 | —25 | — 8 | + 5 |
| Durtje | + 43 | + 67 | —23 | — 5 | + 5 |
| Hazel K. | — 11 | + 3 | —23 | — 6 | + 6 |
| Jane | + 20 | + 41 | —39 | —26 | + 3 |
| Karah | — 20 | — 6 | —35 | —21 | + 2 |
| Nesbit | +186 | +236 | +55 | +90 | +17 |

These cows fall into three groups; one (Bontje, Hazel K., Karah) underfed both as to the digestible protein and total digestible nutrients contents of their rations; two (Durtje, Jane) overfed with digestible protein but underfed with total digestible nutrients; and one (Nesbit) grossly overfed. Obviously under such circumstances, and in view of the small number of records, no average can be established that means much.

Studies made elsewhere show that the carcass of the average calf at birth carries about 28 percent of dry matter, 20 percent of protein and 4 percent of fat. Assuming that the placenta as such is of a similar composition and that it comprises one-half of the weight of the ejecta other than the calf, we have the following comparative statements for the several cows as to the food intake for the entire period of gestation on the one hand and the contents of calf and placenta stated in food nutrient terms on the other hand.

The statement also sets forth the standard maintenance needs for each cow calculated on the basis of her average weight during the first few weeks following service, the left hand figures representing the data calculated used the Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey standards, and the right hand those derived from the use of the Armsby and Eckles (converted) standards. These, also, are calculated to entire gestation period consumption.

| | | Total dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients |
|---|---|---|---|---|---|---|---|---|---|
| | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Bontje | Intake, 275 days | 3,204 | 201 | 1,815 | 2,021 | 3,204 | 201 | 1,815 | 2,021 |
| | Standard maintenance at 1,200 pounds | .... | 235 | 2,428 | 2,664 | .... | 200 | 1,975 | 2,177 |
| | Remaining for fœtal construction | .... | —34 | —613 | —643 | .... | + 1 | —160 | —156 |
| | 100 pounds ejecta | .... | 20 | 9 | 29 | .... | 20 | 9 | 29 |
| Durtje | Intake, 279 days | 3,543 | 371 | 1,897 | 2,288 | 3,543 | 371 | 1,897 | 2,288 |
| | Standard maintenance at 1,274 pounds | .... | 249 | 2,575 | 2,818 | .... | 211 | 2,090 | 2,302 |
| | Remaining for fœtal construction | .... | +122 | —678 | —530 | .... | +160 | —193 | —14 |
| | 100 pounds ejecta | .... | 20 | 9 | 29 | .... | 20 | 9 | 29 |
| Hazel K. | Intake, 276 days | 2,732 | 179 | 1,559 | 1,739 | 2,732 | 179 | 1,559 | 1,739 |
| | Standard maintenance at 1,000 pounds | .... | 196 | 2,024 | 2,220 | .... | 167 | 1,646 | 1,814 |
| | Remaining for fœtal construction | .... | —17 | —465 | —481 | .... | +12 | —87 | —75 |
| | 90 pounds ejecta | .... | 18 | 8 | 26 | .... | 18 | 8 | 26 |
| Jane | Intake, 281 days | 1,925 | 205 | 1,012 | 1,222 | 1,925 | 205 | 1,012 | 1,222 |
| | Standard maintenance at 836 pounds | .... | 165 | 1,699 | 1,863 | .... | 140 | 1,381 | 1,522 |
| | Remaining for fœtal construction | .... | +40 | —687 | —641 | .... | +60 | —369 | —300 |
| | 70 pounds ejecta | .... | 14 | 6 | 21 | .... | 14 | 6 | 21 |
| Karah | Intake, 284 days | 1,931 | 133 | 1,079 | 1,221 | 1,931 | 133 | 1,079 | 1,221 |
| | Standard maintenance at 820 pounds | .... | 163 | 1,683 | 1,849 | .... | 139 | 1,370 | 1,809 |
| | Remaining for fœtal construction | .... | —30 | —604 | —628 | .... | —6 | —290 | —288 |
| | 50 pounds ejecta | .... | 10 | 5 | 15 | .... | 10 | 5 | 15 |
| Nesbit | Intake, 280 days | 5,656 | 588 | 3,024 | 3,612 | 5,656 | 588 | 3,024 | 3,612 |
| | Standard maintenance at 1,000 pounds | .... | 196 | 2,024 | 2,220 | .... | 167 | 1,646 | 1,814 |
| | Remaining for fœtal construction | .... | +392 | +1,000 | +1,392 | .... | +421 | +1,378 | +1,798 |
| | 150 pounds ejecta | .... | 30 | 14 | 44 | .... | 30 | 14 | 44* |

*Nesbit gave 129 pounds of milk during the early part of her gestation period, containing 20, 6.5 and 21.9 pounds respectively of total dry matter, protein and carbohydrates (milk sugar and fat × 2¼). See, also, footnote on page 61.

It will be observed that, speaking in general terms, the first five cows did not consume a sufficient amount of total digestible nutrients to maintain them without loss of live weight, not to speak of fœtal construction, provided one holds to and abides by the standards. (Nesbit, the sixth cow, was an abnormal and need not be considered.) However, in only one case was there much shortage of digestible protein and in that instance the smallest calf was dropped. In view of the fact that these cows with one exception—Karah whose ration was the lowest of all—did well after calving, the writer is inclined to look upon these figures as furnishing additional testimony in favor of a lower maintenance standard than that proposed by Haecker et al., one quite as low as that proposed by Armsby and by Eckles; that, in other words, the lower standard for total digestible nutrients, 6.5 pounds per 1,000 pounds seems sufficient both to maintain the cow and to build fœtal structures. In this connection it should be noted that three of these five lost live weight on calving as compared with their weights at previous calving, the average shrinkage being 3 percent; that one held her weight; and that one gained 4½ percent. The average loss was nil. This is further testimony in behalf of the sufficiency of the lower maintenance ration in respect to its total digestible nutrient content.

It is perfectly clear that fœtal construction makes a relatively small draft upon the carbohydrate content of the ration, if one considers only the figures representing ultimate product and does not take cognizance of the draft made by the metabolic processes involved in fœtal construction. The protein content of the ration, however, was somewhat more heavily drawn upon—to the extent of approximately 10 percent of the gross digestible protein intake, except in the case of the two cows which were fed excessive amounts of this nutrient. This is equivalent to a daily draft of from 0.05 to 0.1 pounds of digestible protein, extending over the whole period of gestation. Obviously the major portion of this draft occurs in the latter portion of gestation when the figures may well become twice or thrice the average. It will be noted that according to the lower standard the digestible protein supply indicated for maintenance purposes was sufficient also to build the fœtus, save in the case of Karah, whose intake was less than 0.5 pounds a day. And thus again, testifies to the sufficiency of the lower standard in respect to its digestible protein weight content.

The pre- and post-parturition histories of these cows were as follows:

Bontje during 80 weeks of low feeding (0 to —1/6 digestible protein, —1/12 to —1/4 total digestible nutrients during gestation) maintained her live weight fairly well. She dropped a full sized bull calf and, during the five weeks succeeding calving, gave an average of 35 pounds of milk daily.

Durtje had plenty and to spare of digestible protein at all times during 73 weeks (+3/7 to +2/3 during gestation), but her total digestible nutrient intake was somewhat low of maintenance requirements even during pregnancy (—1/20 to —1/4). She maintained her live weight well, dropped a normal full sized heifer calf and gave 8,700 pounds of milk and 318 pounds of fat during the ensuing year.

Hazel K., underfed for 75 weeks (0 to —1/10, —1/16 to —1/4 during gestation), maintained her live weight notwithstanding her insufficient ration, calved normally, dropped a good calf, and gave 5,650 pounds milk and 302 pounds of fat during the ensuing year.

Jane, greatly underfed for 63 weeks except perhaps during the last two and a half months of her pregnancy (+1/5 to +3/7 digestible protein, and —1/5 to —3/8 total digestible nutrients), dropped a rather small but normal calf and, during the ensuing year, gave 7,424 pounds milk and 403 pounds fat. Furthermore, she did good service for several years subsequent to her trial.

Karah was fed reasonably well during her 24-weeks maintenance period but her food intake was cut down following service to small figures (—1/16 to +1/5, —1/5 to 1/3). Her calf was small but normal. Her subsequent milk record (3,741 pounds in 13 months) was poor.

Nesbit (III. 7.) was grossly overfed throughout her gestation period (+13/7 to +19/8, +4/7 to +9/10) and dropped a very large and fat calf. She naturally continued in good condition after calving.

## IV. ABORTION

Five pregnant cows failed to carry their calves to full time, two aborting twice. The miscarriages occurred one at five and a half months, two at six and a half months, one at seven months and three at eight and a half months.

Two records are of little or no use owing to the loss of the weight data elsewhere referred to. The statements follow.

IV. 1. ALTJE, grade Holstein, nine years old, served January 10, aborted August 2, 1910, at 204 days, was fed the medium ration. Her feeding record prior to and following service follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 7 | 6. | 12.5 | 3. | 4 | 6. | 12.5 | 3. |
| 4 | 5. | 12.5 | 3. | 5 | 7. | 15. | 4. |
| 2 | 5. | 12.5 | 3. | 4 | 8. | 16. | 4.5 |
| 14 | 5. | 10. | 2.8 | | | | |

Her nutrient intake and comparison records follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E. | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 7 | 10.6 | 6.8 | 1. | 5.7 | 6.7 | 8. | 5.1 | 0.75 | 4.3 | 5.05 | 1,328 | + 7 | +26 | —36 | — |
| 4 | 9.7 | 6.3 | 0.85 | 5.3 | 6.2 | 7.3 | 4.8 | 0.65 | 4. | 4.65 | 1,319 | — 7 | + 9 | —41 | —2 |
| Succeeding service | | | | | | | | | | | | | | | |
| 2 | 9.7 | 6.3 | 0.85 | 5.3 | 6.2 | 7.3 | 4.7 | 0.65 | 4. | 4.65 | 1,333 | — 7 | + 9 | —41 | — |
| 14 | 9.3 | 6. | 0.8 | 5. | 5.8 | 7.1 | 4.6 | 0.6 | 3.8 | 4.4 | 1,306 | —14 | + 1 | —45 | —3 |
| 4 | 11.75 | 7.5 | 0.9 | 6.5 | 7.4 | 9. | 5.7 | 0.7 | 5. | 5.6 | 1,322 | 0 | +18 | —29 | —1 |
| 5 | 14.1 | 9.1 | 1.15 | 7.8 | 9. | 10.2 | 6.6 | 0.85 | 5.7 | 6.55 | 1,383 | +21 | +43 | —17 | +1 |
| 4 | 15. | 9.7 | 1.3 | 8.2 | 9.5 | 10.9 | 7. | 0.95 | 6. | 6.95 | 1,379 | +36 | +60 | —12 | + |
| Ave. | 11.4 | 7.35 | 0.95 | 6.2 | 7.15 | 8.55 | 5.5 | 0.71 | 4.65 | 5.4 | 1,333 | + 1 | +19 | —32 | —1 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Weights in successive five-week sub-periods, 1,318, 1,300, 1,309, 1,316, 1,388, 1,401 pounds. Weight after abortion, 1,310 pounds. Approximate weights: aborted calf 50 pounds, placenta, etc. 20 pounds.

IV. 2. ALTJE, grade Holstein, 13 years old, served May 9, aborted December 1, 1914, at 205 days, was fed the medium protein ration. Her feeding record before and after service follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 8 | 10. | 30. | 2. | 3 | 9.3 | 27.6 | 5.9 |
| 6 | 10. | 30. | 4. | 4 | 10. | 20. | 6. |
| 16 | 10. | 30. | 4. | 6 | 11. | 22. | 6.6 |

Her nutrient intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 8 | 16.3 | 10.3 | 1.05 | 8.5 | 9.55 | 13.6 | 8.6 | 0.9 | 7.1 | 8. | 1,204 | +29 | + 51 | + 5 | +23 |
| 6 | 18.3 | 11.7 | 1.35 | 9.7 | 11.05 | 14.8 | 9.5 | 1.1 | 7.8 | 8.9 | 1,247 | +57 | + 85 | +16 | +37 |
| Succeeding service | | | | | | | | | | | | | | | |
| 16 | 18.5 | 11.6 | 1.35 | 9.8 | 11.15 | 14.8 | 9.3 | 1.1 | 7.8 | 8.9 | 1,254 | +57 | + 85 | +13 | +37 |
| 3 | 18.3 | 12.1 | 1.65 | 10.2 | 11.85 | 14.3 | 9.5 | 1.3 | 8. | 9.3 | 1,283 | +86 | +118 | +17 | +43 |
| 4 | 17.7 | 11.6 | 1.7 | 9.9 | 11.6 | 13.4 | 8.8 | 1.3 | 7.5 | 8.8 | 1,316 | +86 | +118 | +11 | +36 |
| 6 | 20.2 | 12.9 | 1.8 | 11.1 | 12.9 | 15.1 | 9.6 | 1.35 | 8.2 | 9.6 | 1,341 | +93 | +127 | +21 | +48 |
| Ave. | 18.7 | 11.9 | 1.52 | 10.1 | 11.65 | 14.55 | 9.3 | 1.2 | 7.85 | 9.1 | 1,284 | +71 | +102 | +16 | +40 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week sub-periods following service, 1,252, 1,244, 1,264, 1,286, 1,320, 1,341 pounds. Weight after abortion ——. Approximate weights: aborted calf —— pounds, placenta, etc. —— pounds. (Data unavailable because of loss of records. See pages 11-12.)

IV. 3. Sabra, grade Jersey, seven years old, served September 13, 1909, aborted May 25, 1910, at 254 days, was fed the medium protein ration. Her feeding record, which was quite variable before and after service, was as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 17 | 11.6 | 0.6 | 4.3 | 12 | 3.1 | 7.6 | 1.8 |
| 17 | 5.3 | 10. | 3.6 | 19 | 4. | 8. | 2.6 |
| 8 | 3.6 | 7.2 | 3. | 5 | 5.6 | 12. | 3. |
| 17 | 3. | 7. | 2. | | | | |

Her nutrient intake and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E. | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 17 | 14.5 | 9.2 | 1.2 | 7.8 | 9. | 16. | 10.1 | 1.3 | 8.6 | 9.9 | 907 | +86 | +118 | +26 | +52 |
| 17 | 11.1 | 7.2 | 0.9 | 6.1 | 7. | 11.5 | 7.5 | 0.95 | 6.3 | 7.3 | 965 | +36 | + 60 | — 6 | +12 |
| 8 | 8.1 | 5.3 | 0.75 | 4.6 | 5.35 | 8.2 | 5.4 | 0.75 | 4.7 | 5.4 | 985 | + 7 | + 26 | —31 | —17 |
| 17 | 6.5 | 4.2 | 0.5 | 3.6 | 3.1 | 6.9 | 4.5 | 0.55 | 3.8 | 4.4 | 941 | —21 | — 7 | —44 | —32 |
| Succeeding service | | | | | | | | | | | | | | | |
| 12 | 6. | 3.8 | 0.55 | 3.2 | 3.75 | 6.4 | 4. | 0.6 | 3.4 | 4. | 944 | —14 | + 1 | —50 | —38 |
| 19 | 7.6 | 4.9 | 0.7 | 4.1 | 4.8 | 8.2 | 5.3 | 0.75 | 4.4 | 5.2 | 933 | + 7 | + 26 | —34 | —19 |
| 5 | 10.4 | 6.6 | 0.85 | 5.7 | 6.55 | 10.8 | 6.9 | 0.9 | 6. | 6.9 | 962 | +28 | + 51 | —13 | + 6 |
| Ave. | 7.6 | 4.8 | 0.68 | 4.05 | 4.75 | 8.05 | 5.15 | 0.73 | 4.35 | 5.1 | 942 | + 4 | + 23 | —35 | —21 |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Weights in successive five-week periods, 962, 940, 915, 930, 937, 950, 962 pounds. Average weight after abortion, 768 pounds. Loss in weight approximately 190 pounds.

IV. 4. NESBIT, grade Jersey, eight years old, was served September 21, 1915 and aborted June 11, 1916, at almost full time (262 days). She was fed the high protein ration but her nutrient intake was limited. She was dry when served. The loss of the live weight records (pages 11-12) makes it impracticable to make positive deductions; but at least one may query whether there may not have been relation between her sub-standard rationing and the miscarriage. Assuming that her live weight, exclusive of that of the growing fœtus, was 950 pounds—which was her lowest authenticated average live weight prior to or subsequent to this period—her average nutrient intakes were approximately standard or better than standard in respect to digestible protein (0 to $+\frac{1}{6}$) and deficient in respect to total digestible nutrients ($-\frac{3}{10}$ to $-\frac{3}{7}$). No account has been made of the draft of fœtal construction. Her food usage and nutrient intake records follow:

| Weeks | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients |
|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 11+ | 4. | 9. | 2.6 | 7.9 | 5.15 | 0.85 | 4.2 | 5.1 |
| 4 | 4. | 8. | 2.2 | 7.25 | 4.7 | 0.8 | 3.8 | 4.6 |
| 4 | 4. | 7. | 2. | 7.1 | 4.6 | 0.65 | 3.9 | 4.55 |
| 2 | 3. | 7. | 2. | 6.15 | 4. | 0.6 | 3.45 | 4.05 |
| 3 | 3. | 6. | 1.8 | 5.7 | 3.7 | 0.55 | 3.05 | 3.6 |
| 12 | 3. | 5. | 1.4 | 5.1 | 3.3 | 0.45 | 2.8 | 3.25 |
| 1 | 5. | 8.3 | 3.4 | 9.15 | 5.85 | 1. | 4.85 | 5.9 |
| Ave. | 3.5 | 7. | 1.9 | 6.6 | 4.3 | 0.66 | 3.55 | 4.25 |

IV. 5. ISADORE, grade Jersey, 11 years old, was served January 16 and aborted July 5, 1918, at 170 days. She was fed the medium protein ration. Her weight records are missing (see pages 11-12). Her food and nutrient intakes are as follows:

| Weeks | Hay | Silage | Grain | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients |
|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Preceding service | | | | | | | | |
| 10 | 6. | 12. | 3.6 | 10.7 | 6.9 | 0.85 | 6.05 | 6.85 |
| Succeeding service | | | | | | | | |
| 4 | 6. | 12. | 3.6 | 10.7 | 6.9 | 0.85 | 6.05 | 6.85 |
| 7 | 4. | 8. | 2.4 | 7.15 | 4.6 | 0.55 | 4.05 | 4.6 |
| 13 | 6. | 12. | 3.6 | 10.7 | 6.9 | 0.85 | 6.05 | 6.85 |
| Ave. | 5.4 | 10.8 | 3.2 | 9.6 | 6.2 | 0.75 | 5.45 | 6.2 |

Owing to the live weight data loss above noted no exact deductions can be drawn. However, such data as are available indicate that Isadore averages to weigh about 850 pounds when in milk and barren. The fœtus could not have made very large drafts on the food supply, being lost at six months. On this assumption the cow ate considerable excesses of digestible protein during the first month and the last three months (+2/5 to +2/3) and closely standard amounts in the mid-period (—1/10 to +1/10) and 0 to +1/4 and —1/6 to —1/3 total digestible nutrients during the corresponding periods. On the average she probably ate 1/4 to nearly 1/2 more digestible protein but from 1/12 less to 1/8 more total digestible nutrients than standards indicated.

IV. 6. AUGUSTA, grade Jersey, eight years old, served January 27, aborted September 13, 1919, at 229 days, was fed the high protein ration. Her feeding record before and after service was as follows, being identical:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 18 | 6. | 12. | 3.4 | 32 | 6. | 12. | 3.4 |

Her nutrient intakes and comparison data follow:

| Weeks | Actual | | | | | Per 1,000 pounds live weight | | | | | Mean live weight | Nutrient use ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. | A. E. | H. S. | A. E. |
| | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 18 | 10.7 | 6.9 | 1.1 | 5.9 | 7. | 13.3 | 8.6 | 1.35 | 7.4 | 8.75 | 803 | +93 | +125 | +11 | - |
| Succeeding service | | | | | | | | | | | | | | | |
| 32 | 10.7 | 6.9 | 1.1 | 5.9 | 7. | 12.6 | 8.1 | 1.3 | 6.9 | 8.2 | 852 | +86 | +117 | + 3 | - |
| Standards (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0 595 | | 6.48 | 1,000 | | | | |

Average weights in successive five-week sub-periods, 802, 808, 820, 850, 893, 907 pounds. Average weight following abortion, 790 pounds. Approximate weights: aborted calf 75 pounds, placenta, etc. 40 pounds.

IV. 7. ISADORE, grade Jersey, 12 years old, was served June 12, 1919 and aborted February 18, 1920, at 251 days. She received the medium protein ration and was fed very heavily as the following statement as to feeding before and after service amply indicates:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 13 | 12. | 24. | 8. | 10 | 10.1 | 19. | 5.9 |
| 9 | 10.6 | 21.3 | 6.4 | 11 | 12.2 | 22.3 | 7.4 |
| | | | | 15 | 8.3 | 16.8 | 4.9 |

Her nutrient intakes and comparison data follow:

| | Actual | | | | | Per 1,000 pounds live weight | | | | | | Nutrient usage ± as compared with standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | H. S. A. E. | | H. S. A. E. | |
| Weeks | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Mean live weight | Digestible protein | Digestible protein | Total digestible nutrients | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| Preceding service | | | | | | | | | | | | | | | |
| 13 | 24.9 | 16. | 2. | 13.7 | 15.7 | 28.7 | 18.5 | 2.3 | 15.8 | 18.1 | 868 | +229 | +287 | +129 | +178 |
| 9 | 19. | 12.3 | 1.6 | 10.5 | 12.1 | 20.4 | 13.2 | 1.7 | 11.3 | 13. | 932 | +143 | +186 | + 65 | +101 |
| Succeeding service | | | | | | | | | | | | | | | |
| 10 | 17.6 | 11.3 | 1.45 | 9.7 | 11.15 | 18.5 | 11.9 | 1.55 | 10.2 | 11.75 | 952 | +121 | +161 | + 49 | + 82 |
| 11 | 22.8 | 14.7 | 1.9 | 12.6 | 14.5 | 22.4 | 14.5 | 1.85 | 12.4 | 14.25 | 1,016 | +164 | +211 | + 81 | +121 |
| 15 | 15. | 9.7 | 1.25 | 8.3 | 9.55 | 13.5 | 8.7 | 1.15 | 7.5 | 8.65 | 1,109 | + 64 | + 93 | + 9 | + 34 |
| Ave. | 18.1 | 11.7 | 1.48 | 10. | 11.5 | 17.6 | 11.2 | 1.46 | 9.7 | 11.2 | 1,039 | +109 | +145 | + 41 | + 73 |
| Standard (maintenance): Haecker, Savage, modified Wolff-Lehmann, Woll-Humphrey | | | | | | | | 0.7 | | 7.93 | 1,000 | | | | |
| Standards (maintenance): Armsby, Eckles (converted) | | | | | | | | 0.595 | | 6.48 | 1,000 | | | | |

Average weights for successive five-week sub-periods following service, 951, 954, 988, 1,060, 1,090, 1,108, 1,128 pounds. Average weight after abortion, 990 pounds. Approximate weights: aborted calf 95 pounds, placenta, etc. 45 pounds.

Handling the above data (exclusive of IV. 4 and 5) in the same manner as the corresponding material in Section III was handled, we have the following tabular statement:

| | | Haecker & Savage | | | | Eckles & Armsby | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Total dry matter | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients |
| | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Altje | Intake, 204 days | 2,326 | 194 | 1,265 | 1,459 | 2,326 | 194 | 1,265 | 1,459 |
| | Standard maintenance at 1,320 pounds | .... | 188 | 1,946 | 2,137 | .... | 160 | 1,583 | 1,744 |
| | Remaining for fœtal construction | .... | +6 | —681 | —678 | .... | +34 | —318 | —285 |
| | 60 pounds ejecta | .... | 12 | 5 | 17 | .... | 12 | 5 | 17 |
| Altje | Intake, 205 days | 3,834 | 312 | 2,071 | 2,388 | 3,834 | 312 | 2,071 | 2,388 |
| | Standard maintenance at 1,253 pounds | .... | 180 | 1,853 | 2,036 | .... | 153 | 1,509 | 1,667 |
| | Remaining for fœtal construction | .... | +132 | +218 | +352 | .... | +159 | +562 | +721 |
| | Ejecta—Data unavailable. | | | | | | | | |
| Sabra | Intake, 254 days | 1,930 | 173 | 1,029 | 1,207 | 1,930 | 173 | 1,029 | 1,207 |
| | Standard maintenance at 942 pounds | .... | 167 | 1,730 | 1,897 | .... | 142 | 1,407 | 1,549 |
| | Remaining for fœtal construction | .... | +6 | —701 | —690 | .... | +31 | —378 | —342 |
| | 160 pounds ejecta | .... | 32* | 13* | 45* | .... | 32* | 13* | 45* |
| Augusta | Intake, 229 days | 2,450 | 252 | 1,351 | 1,603 | 2,450 | 252 | 1,351 | 1,603 |
| | Standard maintenance at 810 pounds | .... | 130 | 1,342 | 1,470 | .... | 110 | 1,090 | 1,202 |
| | Remaining for fœtal construction | .... | +122 | +9 | +133 | .... | +142 | +261 | +401 |
| | 90 pounds ejecta | .... | 18 | 8 | 26 | .... | 18 | 8 | 26 |
| Isadore | Intake, 251 days | 4,543 | 371 | 2,510 | 2,887 | 4,543 | 371 | 2,510 | 2,887 |
| | Standard maintenance at 952 pounds | .... | 167 | 1,728 | 1,895 | .... | 142 | 1,405 | 1,549 |
| | Remaining for fœtal construction | .... | +204 | +728 | +992 | .... | +229 | +1,105 | +1,338 |
| | 110 pounds ejecta | .... | 22 | 10 | 32 | .... | 22 | 10 | 32 |

*Doubtless an overstatement.

The conclusions to be drawn are much as in Section III. In two instances, Altje (first abortion) and Sabra, there was a decided shortage of carbohydrates and fat and, consequently, of total digestible nutrients; yet both cows did admirably, their misfortune and low plane of nutrition to the contrary notwithstanding. Plenty of digestible protein was always available to supply fœtal needs, except perhaps in Sabra's case.

It seems fair to assume that, aside from the drafts made on the digestible protein intake during pregnancy, which in the last section (page 64) was stated to approximate 10 percent of the gross digestible protein intake in case the cow calved at full time, little call is made upon the total digestible nutrient food intake in connection with fœtal construction *per se* and apart from the call made thereon by the metabolic processes involved.

The pre- and post-parturition histories of these cows and of two whose data are not included for reasons heretofore indicated are as follows:

Altje aborted twice (1910, 1914). She was somewhat underfed during her first unsuccessful gestation ($0$ to $+\frac{1}{5}$, $-\frac{1}{6}$ to $-\frac{1}{3}$). Four months after abortion she was served and calved normally (1911) and calved normally once again (1912). Following her first abortion for the ensuing six months she averaged daily 30.8 pounds of milk and a little over a pound of fat. She was vastly overfed during the second unsuccessful gestation ($+\frac{7}{10}$ to $+\frac{10}{10}$, $+\frac{1}{6}$ to $+\frac{2}{5}$); but, following her second abortion, she gave very little milk, ran down rapidly and three months later was killed. A wire was found in her liver.

Nesbit was fed a sufficiency of protein but an insufficiency of total digestible nutrients prior to service and a decreasing supply of food after service, decreasing moreover as gestation advanced, averaging $-\frac{1}{12}$ to $+\frac{1}{10}$, $-\frac{3}{8}$ to $-\frac{3}{7}$. She aborted at eight and a half months, but, notwithstanding, gave 15.5 pounds of milk and 0.75 pounds of fat a day for seven months following abortion. She calved normally twice later on in the trials but gave small amounts of milk.

Sabra was underfed, as compared with standards, both before and after service ($\frac{1}{25}$ $+\frac{1}{4}$, $-\frac{1}{3}$ $-\frac{1}{5}$). She gave during the five months following abortion an average of 22 pounds of milk a day and 1.2 pounds fat, notwithstanding the low plane of her previous nutrition and her misfortune. Later she dropped two calves at full time and remained for three more years in service in the trials.

Augusta, fed an ample ration ($+\frac{7}{8}$ $+\frac{7}{6}$, $+\frac{1}{33}$ $+\frac{1}{4}$), gave a small amount of milk for five months and, being along in years, was sold.

Isadore, fed a decidedly insufficient ration for more than a year—assuming that her weight was about as it had been earlier and later—aborted in 1918 and again 19 months later, in 1920. She gave a fair amount of milk following her first abortion, but, although very heavily fed before and after service in 1919-20 ($+\frac{11}{10}$ $+\frac{10}{7}$, $+\frac{2}{5}$ $+\frac{3}{4}$), she gave only about 11 pounds of milk daily after her second mishap.

# V-VII. MAINTENANCE AND LACTATION

## V. MAINTENANCE AND LACTATION FOR LESS THAN 12 MONTHS

Nine cows contributed testimony to this phase of the study, three twice and two thrice, a total of 16 records. Three were grade Holsteins, five grade Jerseys, and one a registered Ayrshire.

In Sections V-VIII, inclusive, owing to the introduction of the milk factor into the equation and the consequent increased complexity of the tabular matter, it has seemed best to simplify the statement of food intake and to omit the statements of "total dry matter," "digestible dry matter" and "digestible carbohydrates and fat," stating simply, the "digestible protein" and the "total digestible nutrients." Of course the latter figure is always practically identical with the "digestible dry matter"; and "digestible carbohydrates and fat" can always be determined by subtraction by any one who may happen to be interested.

V. 1. ALTJE, grade Holstein, 10 years old, was in milk 76 days subsequent to calving and prior to service, September 17-December 4. 1911. She was fed a nearly uniform medium protein ration as follows:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 8 | 12 | 30. | 9.9 | 3 | 12. | 36. | 10. |

This ration carried per 1,000 pounds of live weight, 2.05 pounds digestible protein and 13.7 pounds total digestible nutrients and, actually, 2.55 and 17.1 pounds respectively. She averaged 35 pounds of milk and 1.17 pounds fat and maintained a closely even weight, gaining slightly. Her comparison statements follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,245 pounds.. | 0.87 | 9.87 | 0.87 | 9.87 | 0.741 | 8.07 |
| Milk, 35 pounds, 3¼%..... | 1.68 | 10.47 | 2.065 | 10.61 | 2.135 | 10.22 |
| Total maintenance and milk (calculated) .......... | 2.55 | 20.34 | 2.935 | 20.48 | 2.876 | 18.29 |
| Total maintenance and milk (actual) ............ | 2.55 | 17.1 | 2.55 | 17.1 | 2.55 | 17.1 |
| ± ..................... | 0 | —16 | —13 | —17 | —11 | —6 |
| Armsby (conv.) standard[1]. | 2.578 | 2.55 | — 1% | 16.61 | 17.1 | + 3% |

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[1] As is explained at some length on page 21, the Armsby data are printed in this fashion throughout the discussion on pages 74 to 139 (sections V-VIII) in order to secure perpendicularity of tabular matter. The six figures from left to right represent, respectively, 2.578, the calculated digestible protein, stated as pounds, needed, according to Armsby, for maintenance and milk manufacture by a 1,245-pound cow yielding 35 pounds of 3¼ percent milk; 2.55 the actual usage, stated as pounds, by the cow;—1 percent, the percentage difference between 2.578 and 2.55; 16.61, the calculated digestible dry matter needed, according to Armsby, for the maintenance and milk manufacture, stated as pounds, by a 1,245-pound cow yielding 35 pounds of 3¼ percent milk; 20.77, the actual usage, stated as pounds, by the cow; +28 percent, the percentage differences between 16.28 and 20.77. The figures are precisely analogous to those in the three lower horizontal lines.

Her digestible protein and total digestible nutrient intakes were respectively from 0 to ⅛ and from 0 to ⅙ deficient. In spite of the constant display of minus signs her production record was good.

V. 2. BONTJE, grade Holstein, five years old, was in milk 154 days subsequent to calving and prior to service, October 24, 1907-March 26, 1908. Her low protein ration was increased slightly as lactation advanced but remained fairly constant after the first week, increases being within a 5 percent limit of variation. Her feeding record was:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 3 | 15.3 | 33. | 9.1 | 7 | 16. | 40. | 11.4 |
| 12 | 16. | 33.3 | 13. | | | | |

She ate per 1,000 pounds live weight 1.73 pounds digestible protein and 17.2 pounds total digestible nutrients and, actually, 2.09 and 20.77 pounds. Her comparison statements follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. |
| Maintenance, 1,211 pounds.. | 0.848 | 9.60 | 0.848 | 9.60 | 0.721 | 7.85 |
| Milk, 34.6 pounds, 3¼%... | 1.661 | 10.31 | 2.041 | 10.48 | 2.111 | 10.10 |
| Total maintenance and milk (calculated) .......... | 2.509 | 19.91 | 2.889 | 20.08 | 2.832 | 17.95 |
| Total maintenance and milk (actual) ............. | 2.09 | 20.77 | 2.09 | 20.77 | 2.09 | 20.77 |
| ± ...................... | —17 | +4 | —28 | +4 | —26 | +16 |
| Armsby (conv.) standard.. | 2.540 | 2.09 | —18% | 16.28 | 20.77 | +28% |

Bontje's digestible protein intake was sub-standard, the deficiency ranging from ⅙ to 3/10, but her total digestible nutrient consumption exceeded standard requirements by from 1/25 to 3/10. She gained 4 percent in live weight during the five months and seemingly had enough to eat in view of her good milk and fat yields, 34.6 and 1.12 pounds respectively.

V. 3. BONTJE, grade Holstein, 11 years old, was in milk for 99 days subsequent to calving and prior to service, June 5-September 15, 1914. She was fed an essentially unchanged low protein ration in so far as its content of digestible nutrients was concerned. Her feeding record was:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 4 | 10. | 30. | 6.6 | 3 | 8. | 30. | 7.9 |
| 8 | 8. | 30. | 9. | | | | |

After the first three days in milk her ration averaged per 1,000 pounds live weight 1.41 pounds digestible protein and 12.25 pounds total digestible nutrients and, actually, 1.53 and 13.3 pounds. She ate much less and gave less and poorer milk than during the V. 2 trial just discussed, averaging 25 pounds of milk and 0.69 pounds of fat. Her comparison statements follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,085 pounds.. | 0.76 | 8.60 | 0.760 | 8.60 | 0.646 | 7.03 |
| Milk, 25 pounds, 2¾%..... | 1.16 | 6.73 | 1.375 | 6.80 | 1.475 | 6.80 |
| Total maintenance and milk (calculated) .......... | 1.92 | 15.33 | 2.135 | 15.40 | 2.121 | 13.83 |
| Total maintenance and milk (actual) .............. | 1.53 | 13.3 | 1.53 | 13.3 | 1.53 | 13.3 |
| ± ..................... | —20 | —13 | —28 | —14 | —28 | —4 |
| Armsby (conv.) standard.. | 1.896 | 1.53 | —19% | 12.48 | 13.3 | + 7% |

As is pointed out above, Bontje ate only two-thirds as much as in the V. 2 trial and gave only two-thirds as much milk and of poorer quality. Furthermore, she lost 4 percent in live weight instead of gaining 4 percent. Her food intake was sub-standard to the extent of ⅕ to ³⁄₁₀ in respect to digestible protein and was from ¹⁄₁₄ excessive to ⅐ deficient in its total digestible nutrient contents, according to the standard used. She does not seem to have had a fair chance to do good work. She dried off more promptly than usual and at the next calving lost a quarter of her udder and was discarded.

V. 4. 'DURTJE, grade Holstein, nine years old, was in milk 232 days subsequent to calving and prior to service, October 20, 1910, to June 9, 1911. Her high protein ration varied somewhat as to the digestible nutrients contents, extremes being about 15 percent apart. However, excluding the first two and last seven weeks, the food intake was very uniform. Her feeding record was:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 2 | 14. | 35. | 7.2 | 14 | 15. | 40. | 9.5 |
| 10 | 15. | 36. | 10. | 7 | 12. | 40. | 9. |

She averaged to eat per 1,000 pounds of live weight 2.58 pounds digestible protein and 14.6 pounds total digestible nutrients and, actually, 3.33 and 18.8 pounds. Her daily average yields were 31.8 pounds milk and 1.08 pounds fat, and, during the first 20 weeks, 35.8 and 1.23 pounds. Her live weight was closely consistent throughout the entire course of the trial. Her comparison statements—excluding the first week—follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,290 pounds.. | 0.903 | 10.23 | 0.903 | 10.23 | 0.768 | 8.36 |
| Milk, 31.8 pounds, 3½%.... | 1,558 | 9.95 | 1,940 | 10.14 | 1.972 | 9.60 |
| Total maintenance and milk (calculated) .......... | 2.461 | 20.18 | 2.843 | 20.37 | 2.74 | 17.96 |
| Total maintenance and milk (actual) ............. | 3.33 | 18.8 | 3.33 | 18.8 | 3.33 | 18.8 |
| ± ...................... | +35 | —7 | +17 | —8 | +22 | +5 |
| Armsby (conv.) standard.. | 2.485 | 3.33 | +34% | 16.53 | 18.8 | +14% |

Durtje's digestible protein intake exceeded standard requirements by ⅙ to ⅓, while her total digestible nutrient consumption varied from 1/7 excess to 1/14 deficiency. She seems to have had quite enough.

V. 5. HAZEL K., grade Jersey, four years old, was in milk 327 days, August 22, 1917 to July 14, 1908, and then went dry while farrow. Her low protein ration varied considerably as appears below, being curtailed as she advanced in lactation.

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 7 | 26.5 | 0 | 8.6 | 4 | 14. | 30. | 3.8 |
| 18 | 14.6 | 31.4 | 9.4 | 12 | 14.6 | 26.4 | 1.8 |
| 6 | 14. | 30. | 6.7 | | | | |

Her food intake, milk and fat yield statements and comparison with standard dicta expressed in terms of percentages, plus or minus as the case may be, are shown below:[1]

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| 7 | 925 | 1.9 | 17.5 | 2.05 | 19. | 23.1 | 1.08 | — 5 to —17 | + 7 to +29 |
| 18 | 977 | 1.8 | 17.9 | 1.85 | 18.3 | 19.7 | 1.03 | — 6 to —16 | +12 to +35 |
| 6 | 1,001 | 1.55 | 16. | 1.55 | 16. | 10.8 | 0.61 | + 1 to +14 | +27 to +51 |
| 4 | 1,003 | 1.3 | 14.45 | 1.3 | 14.4 | 7.4 | 0.39 | + 4 to +19 | +31 to +58 |
| 12 | 1,013 | 1.1 | 12.6 | 1.1 | 12.5 | 5.5 | 0.3 | 0 to +12 | +22 to +47 |
| Ave. | 984 | 1.55 | 15.85 | 1.59 | 16.2 | 14.4 | 0.74 | 0 to —12 | +15 to +38 |

Her comparison statements, dealing with the entire feeding period as a unit, are as follows:

---

[1] Data such as are presented in the subjoined table are furnished only when considerable variation occurred in the nutrient intake as the trial progressed.

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 984 pounds... | 0.689 | 7.81 | 0.689 | 7.81 | 0.585 | 6.38 |
| Milk, 14.4 pounds, 5¼%.... | 0.892 | 5.92 | 1.081 | 6.01 | 1.106 | 5.92 |
| Total maintenance and milk (calculated) .......... | 1.581 | 13.73 | 1.77 | 13.82 | 1.691 | 12.30 |
| Total maintenance and milk (actual) .............. | 1.55 | 15.85 | 1.55 | 15.85 | 1.55 | 15.85 |
| ± ...................... | —2 | +15 | —12 | +15 | —8 | +29 |
| Armsby (conv.) standard.. | 1.557 | 1.55 | 0 | 11.46 | 15.85 | +38% |

Hazel K. gave a fair yield—14.4 pounds of milk and 0.74 pounds of fat—and gained nearly 10 percent in live weight. She always had enough to eat, so far as total digestible nutrients were concerned, though at best a bare sufficiency of digestible protein, the figures being for digestible protein and total digestible nutrients respectively from 0 to ⅛ deficiency, from ⅐ to ⅜ excess. Her protein shortage occurred during the first half of the period only. Her considerable gain in live weight testifies to her ample feeding.

V. 6. HAZEL K., grade Jersey, seven years old, was in milk for 189 days subsequent to calving and prior to service, August 31, 1910 to March 8, 1911, being fed the low protein ration. Her food intake was reasonably uniform, except that for a month at the outset it was but three-fourths that of the ensuing five months, being as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 4 | 12. | 12.5 | 7.3 | 23 | 12.6 | 30. | 7.9 |

She averaged to eat actually and per 1,000 pounds of live weight and to yield in milk and fat, during the initial and the following five months—the latter treated as a unit—the amounts indicated below. The table also sets forth the usual comparisons with standards.

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | | Total digestible nutrients ± of standards | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| 4 | 1,005 | 1.45 | 12.9 | 1.45 | 12.85 | 19.5 | 0.99 | —23 to | —23 | — 2 to | —19 |
| 23 | 948 | 1.7 | 15.7 | 1.8 | 16.6 | 19.6 | 1.07 | —11 to | —22 | — 2 to | +18 |
| Ave. | 957 | 1.67 | 15.25 | 1.75 | 15.9 | 19.6 | 1.06 | —13 to | —23 | — 5 to | +14 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 957 pounds... | 0.67 | 7.59 | 0.67 | 7.59 | 0.569 | 6.20 |
| Milk, 19.6 pounds, 5½%.... | 1.254 | 8.31 | 1.509 | 8.45 | 1.548 | 8.47 |
| Total maintenance and milk (calculated) .......... | 1.924 | 15.9 | 2.176 | 16.04 | 2.117 | 14.67 |
| Total maintenance and milk (actual) .............. | 1.67 | 15.25 | 1.67 | 15.25 | 1.67 | 15.25 |
| ± ...................... | —13 | —4 | —23 | —5 | —21 | +4 |
| Armsby (conv.) standard.. | 1.921 | 1.67 | —13% | 13.35 | 15.25 | +14% |

The cow was fed a ⅕ heavier ration after the first month elapsed than during the first month and gave throughout the five months of heavier feeding as much milk and more fat as during her first month; but she shrank 5 percent in live weight in doing it. She ate on the average from ⅛ to ¼ too little digestible protein and from 1/20 deficiency to ⅐ excess of total digestible nutrients; but during her first month in lactation digestible protein was ¼ to ⅓ and total digestible nutrient 0 to ⅕ or more lacking. In view of her restricted ration her average daily milk and fat yields were quite satisfactory.

V. 7. HAZEL K., grade Jersey, nine years old, was in milk 56 days subsequent to calving and prior to service, December 15, 1911 to February 9, 1912. She was fed a low protein ration, as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs | | lbs. | lbs. | lbs. |
| 1 | 10. | 20. | 8.6 | 7 | 10. | 30. | 8.6 |

Her ration afforded per 1,000 pounds live weight 1.74 pounds digestible protein and 15.7 pounds total digestible nutrients and actually, 1.56 and 14 pounds. She gave 24.3 pounds milk and 1.13 pounds fat daily during these two months and maintained an essentially unchanged live weight. However, after service she dried off somewhat quickly and gave all told only 4,700 pounds of milk and 177 pounds of fat during the lactation. Her comparison statements follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 894 pounds .. | 0.626 | 7.09 | 0.626 | 7.09 | 0.532 | 5.79 |
| Milk, 24.3 pounds 4½%.... | 1.385 | 9.04 | 1.677 | 9.21 | 1.677 | 8.65 |
| Total maintenance and milk (calculated) .......... | 2.011 | 16.13 | 2.303 | 16.3 | 2.209 | 14.44 |
| Total maintenance and milk (actual) ............. | 1.56 | 14. | 1.56 | 14. | 1.56 | 14. |
| ± ...................... | —22 | —13 | —32 | —14 | —29 | —3 |
| Armsby (conv.) standard.. | 2.039 | 1.56 | —24% | 13.42 | 14. | + 5% |

Hazel K. ate from ⅕ to ⅓ too little digestible protein and from ⅐ too little to ⅒ too much total digestible nutrients. She did well during these two months, notwithstanding a somewhat scanty ration which not unlikely may have been a prime factor in her rapid drying off and relatively small total milk yield.

V. 8. JANE, grade Jersey, four years old, a small cow, was in milk for 335 days subsequent to calving, August 7, 1907 to July 9, 1908, and went dry while farrow. She was fed the high protein ration as follows:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 10 | 25. | — | 9. | 5 | 8. | 20. | 6. |
| 5 | 12. | 31. | 9. | 6 | 8. | 20. | 4.6 |
| 6 | 8. | 25. | 9. | 16 | 8. | 20. | 3.8 |

She left large amounts of food uneaten. Her food intakes, milk and fat yields and comparison statements follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 10 | 791 | 2.75 | 17. | 3.5 | 21.5 | 19.1 | 0.95 | +40 to +62 | +21 to +46 |
| 5 | 818 | 2.6 | 16.1 | 3.2 | 19.7 | 16.8 | 0.98 | +34 to +53 | +14 to +35 |
| 6 | 798 | 2.4 | 13.7 | 3. | 17.2 | 13.1 | 0.76 | +48 to +68 | +11 to +33 |
| 5 | 785 | 1.9 | 10.8 | 2.4 | 13.8 | 10.5 | 0.6 | +36 to +57 | — 2 to +19 |
| 6 | 787 | 1.6 | 9.8 | 2.05 | 12.5 | 9.2 | 0.56 | +24 to +40 | — 6 to +13 |
| 16 | 791 | 1.45 | 9.4 | 1.85 | 11.9 | 7.6 | 0.46 | +24 to +41 | — 3 to +16 |
| Ave. | 794 | 2.02 | 12.35 | 2.55 | 15.6 | 12.15 | 0.68 | +35 to +54 | + 7 to +29 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 794 pounds.. | 0.556 | 6.30 | 0.556 | 6.30 | 0.471 | 5.15 |
| Milk, 12.15 pounds, 5½%.. | 0.777 | 5.15 | 0.935 | 5.24 | 0.960 | 5.25 |
| Total maintenance and milk (calculated) ............ | 1.333 | 11.45 | 1.491 | 11.54 | 1.431 | 10.4 |
| Total maintenance and milk (actual) .............. | 2.02 | 12.35 | 2.02 | 12.35 | 2.02 | 12.35 |
| ± ........................ | +52 | +8 | +35 | +7 | +42 | +19 |
| Armsby (conv.) standard.. | 1.31 | 2.02 | +54% | 9.58 | 12.35 | +29% |

Obviously, Jane was greatly overfed, the surplusages in digestible protein and total digestible nutrients respectively being from 1/3 to 4/7 and 1/14 to 3/10; yet, notwithstanding, she made only a little milk and fat, daily averages of 12.15 and 0.68 pounds respectively during 11 months and yielding all told only 4,089 and 227 pounds respectively. Furthermore, no cow in the long series of years maintained a more consistent live weight. It is not clear what she did with her food.

V. 9. JANE, grade Jersey, seven years old, was in milk for 173 days subsequent to calving and prior to service, June 15-December 5, 1910. She was fed the high protein ration as shown below:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 3 | 11.3 | 12.5 | 7.3 | 5 | 13.7 | 33. | 8.5 |
| 10 | 12. | 25. | 8. | 7 | 14. | 36. | 8. |

Her food intake, milk and fat yields and comparison data follow:

| | | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | Live weight | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 3 | 825 | 2.3 | 13. | 2.8 | 15.8 | 25.3 | 1.12 | — 1 to +14 | — 2 to —19 |
| 10 | 832 | 2.6 | 15.7 | 3.1 | 18.8 | 27.8 | 1.25 | + 4 to +20 | — 8 to +12 |
| 5 | 868 | 2.7 | 17.3 | 3.1 | 19.9 | 24.5 | 1.19 | — 1 to +27 | + 6 to +24 |
| 7 | 876 | 2.7 | 17.3 | 3.1 | 19.8 | 21.3 | 1.21 | +20 to +33 | + 8 to +26 |
| Ave. | 851 | 2.6 | 16.1 | 3.06 | 19. | 25. | 1.21 | + 8 to +24 | — 5 to +15 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 851 pounds... | 0.596 | 6.75 | 0.596 | 6.75 | 0.506 | 5.51 |
| Milk, 25. pounds, 5%...... | 1.5 | 9.95 | 1.825 | 10.13 | 1.850 | 9.73 |
| Total maintenance and milk (calculated) .......... | 2.096 | 16.7 | 2.421 | 16.88 | 2.356 | 15.24 |
| Total maintenance and milk (actual) .............. | 2.6 | 16.1 | 2.6 | 16.1 | 2.6 | 16.1 |
| ± ...................... | +24 | —4 | +7 | —5 | +10 | +6 |
| Armsby (conv.) standard. | 2.156 | 2.6 | +21% | 14.01 | 16.1 | +15% |

Jane was fed more digestible protein than she needed (+1/14 to +1/4) and as much or more total digestible nutrients than she needed

(—1/20 to +1/7). She kept up her milk flow and gained 6 percent in live weight. Jane did well with her food.

V. 10. **SABRA**, grade Jersey, four years old, was in milk 329 days subsequent to calving, August 14, 1907 to July 12, 1908, and went dry while farrow. Her feeding—the medium protein ration—was quite diverse as is shown by the following statement:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 10 | 28.5 | ... | 9. | 7 | 12. | 30. | 5. |
| 10 | 13. | 32.5 | 8. | 8 | 12. | 30. | 3.6 |
| 5 | 12. | 25. | 6.4 | 7 | 12. | 28. | 2.7 |

Her food intake, milk and fat yields and comparison data follow:

| | | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | Live weight | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 10 | 851 | 2.55 | 19. | 3. | 22.4 | 15.6 | 1.01 | +33 to +51 | +33 to +58 |
| 10 | 892 | 1.95 | 16.4 | 2.2 | 18.4 | 12.2 | 0.74 | +17 to +38 | +26 to +56 |
| 5 | 888 | 1.75 | 13.6 | 1.95 | 15.3 | 10.6 | 0.67 | +15 to +31 | +12 to +34 |
| 7 | 892 | 1.55 | 13.4 | 1.75 | 15. | 8.9 | 0.58 | +12 to +29 | +18 to +42 |
| 8 | 898 | 1.45 | 12.9 | 1.6 | 14.4 | 7.4 | 0.49 | +15 to +33 | +21 to +45 |
| 7 | 912 | 1.3 | 12.3 | 1.45 | 13.5 | 6.3 | 0.36 | +11 to +31 | +20 to +48 |
| Ave. | 887 | 1.82 | 15. | 2.05 | 16.9 | 10.55 | 0.67 | +21 to +38 | +25 to +50 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 887 pounds... | 0.621 | 7.03 | 0.621 | 7.03 | 0.528 | 5.75 |
| Milk, 10.55 pounds, 6¼%.. | 0.733 | 4.91 | 0.875 | 4.96 | 0.907 | 5.41 |
| Total maintenance and milk (calculated) .......... | 1.354 | 11.94 | 1.496 | 11.99 | 1.435 | 11.16 |
| Total maintenance and milk (actual) .............. | 1.82 | 15. | 1.82 | 15. | 1.82 | 15. |
| ± ...................... | +35 | +26 | +21 | +25 | +27 | +34 |
| Armsby (conv.) standard.. | 1.314 | 1.82 | +38% | 10.00 | 15. | +50% |

Sabra was greatly overfed, as judged by standards, receiving from ⅕ to ⅜ too much digestible protein and from ¼ to ½ too much total digestible nutrients; yet she made but little milk, on the average 10.55 pounds milk and 0.67 pounds of fat, and only 3,519 and 223 pounds during the lactation. However, she gained somewhat in live weight, about 5 percent during the first half of the lactation and 2 percent more at its close. She consumed considerably more food than she should have—as judged by standards—in view of her low yield and not very large gain in weight.

V. 11. SABRA, grade Jersey, eight years old was in milk for 160 days subsequent to calving and prior to service, July 14 to December 26, 1911. Her medium protein ration was an almost absolutely uniform one. Her feeding record was:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 7 | 10. | 30. | 8 | 16 | 10. | 30. | 8.6 |

Her comparison statements follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein lbs. | Total digestible nutrients lbs. | Digestible protein lbs. | Total digestible nutrients lbs. | Digestible protein lbs. | Total digestible nutrients lbs. |
| Maintenance, 863 pounds.. | 0.604 | 6.84 | 0.604 | 6.84 | 0.513 | 5.59 |
| Milk, 20.1 pounds, 5½%.... | 1.286 | 8.52 | 1.548 | 8.66 | 1.590 | 8.68 |
| Total maintenance and milk (calculated) .......... | 1.89 | 15.36 | 2.152 | 15.5 | 2.103 | 14.27 |
| Total maintenance and milk (actual) ............. | 2.12 | 14.85 | 2.12 | 14.85 | 2.12 | 14.85 |
| ± ...................... | +12 | —3 | —1 | —4 | +1 | +4 |
| Armsby (conv.) standard.. | 1.901 | 2.12 | +12% | 12.93 | 14.85 | +15% |

Sabra averaged 20.1 pounds of milk and 1.07 pounds fat during the five and one-half months and she gained about 5 percent in live weight. She ate enough digestible protein (0 to +⅛) and received from a slight deficiency (—1/33) to a fair surplus (+1/7) of total digestible nutrients, according to the standard with which her nutrient intake is compared. She did fairly well with what she had to eat.

V. 12. EVELYN, grade Holstein, five years old, was in milk 213 days subsequent to calving and prior to ineffective service, September 29, 1912, to May 2, 1913, which occurred coincident with drying off. She was fed the low protein ration, her rations changing as follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 2 | 8. | 15. | 7.6 | 5 | 12. | 36. | 7.6 |
| 5 | 10.5 | 30. | 8. | 5 | 12. | 36. | 5.6 |
| 5 | 12. | 36. | 9.3 | 3 | 11.7 | 36. | 2.8 |
| 5 | 14. | 36. | 8.6 | | | | |

Her food intake and milk and fat yields and comparison data follow:

| Duration | Live weight | Actual |  | Per 1,000 pounds live weight |  | Actual |  | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield |  |  |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 2 | 950 | 1.25 | 10.8 | 1.35 | 11.4 | 30.8 | 1.42 | —28 to —37 | —32 to —44 |
| 5 | 950 | 1.5 | 14. | 1.6 | 14.7 | 26.9 | 1.06 | —29 to —38 | — 3 to —18 |
| 5 | 997 | 1.75 | 16.3 | 1.75 | 16.3 | 22.2 | 0.87 | — 7 to —18 | + 4 to +28 |
| 5 | 1,027 | 1.75 | 17.1 | 1.7 | 16.7 | 19.9 | 0.79 | — 1 to —12 | +14 to +38 |
| 5 | 1,058 | 1.6 | 15.5 | 1.5 | 14.6 | 12.9 | 0.54 | 0 to +13 | +19 to +47 |
| 5 | 1,096 | 1.45 | 14.5 | 1.3 | 13.2 | 5.2 | 0.23 | +30 to +49 | +36 to +63 |
| 3 | 1,141 | 1.15 | 12.7 | 1. | 11.1 | 2.1 | 0.08 | +23 to +45 | +30 to +61 |
| Ave. | 1,032 | 1.55 | 14.9 | 1.5 | 14.4 | 16.8 | 0.69 | — 3 to —15 | + 4 to +28 |

|  | Haecker |  | Savage |  | Eckles (converted) |  |
|---|---|---|---|---|---|---|
|  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
|  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,032 pounds.. | 0.723 | 8.18 | 0.723 | 8.18 | 0.614 | 6.69 |
| Milk, 16.8 pounds, 4¼%... | 0.932 | 6.01 | 1.126 | 6.13 | 1.126 | 5.71 |
| Total maintenance and milk (calculated) .......... | 1.655 | 14.19 | 1.849 | 14.31 | 1.740 | 12.40 |
| Total maintenance and milk (actual) ............. | 1.55 | 14.9 | 1.55 | 14.9 | 1.55 | 14.9 |
| ± ...................... | —6 | +5 | —17 | +4 | —11 | +20 |
| Armsby (conv.) standard.. | 1.622 | 1.55 | — 4% | 11.72 | 14.9 | +28% |

Evelyn was underfed during the initial seven weeks but sufficiently fed the remaining 23 weeks (—1/6 to +4/7, +1/25 to +3/4). Her average intakes were —1/33 to —1/7, +1/25 to +3/10. She only made an average of 16.8 and 0.69 pounds respectively of milk and fat and a total during the entire lactation of 3,610 and 141 pounds. She consistently gained in live weight, closing the seven months weighing almost 200 pounds more than at the outset, a gain of 20 percent in live weight. Evelyn was always an inferior animal and was kept simply because of the exigencies of the trial.

V. 13. LANTA 2ND, registered Ayrshire, four years old, was in milk for 316 days subsequent to calving, August 20, 1912 to July 3, 1913, drying off while farrow. She shrank rapidly in milk flow from the very outset, giving only two-thirds the initial flow two months and only two-fifths the initial flow three months after calving. Consequently she was given a decreasing medium ration as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 1 | 6. | 15. | 5. | 5 | 10. | 30. | 3. |
| 7 | 7.6 | 15. | 8. | 5 | 10. | 30. | 2.6 |
| 5 | 10. | 30. | 9.6 | 5 | 9. | 30. | 2.2 |
| 5 | 10. | 30. | 7. | 5 | 7. | 14. | 1.2 |
| 5 | 10. | 30. | 4. | 2 | 4. | 8. | 0.6 |

Her food intake, milk and fat yields and comparison data follow:

| | | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | Live weight | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 1 | 1,045 | 1.35 | 9.2 | 1.3 | 8.8 | 20. | 0.75 | —23 to —32 | —25 to —39 |
| 7 | 1,045 | 1.9 | 10.8 | 1.8 | 10.3 | 29.8 | 1.06 | —13 to —25 | —26 to —39 |
| 5 | 999 | 2.25 | 14.45 | 2.25 | 14.45 | 16.6 | 0.57 | +30 to +51 | +11 to +34 |
| 5 | 1,020 | 1.85 | 13.2 | 1.8 | 12.9 | 11.6 | 0.40 | +30 to +50 | +12 to +37 |
| 5 | 1,054 | 1.35 | 11.5 | 1.3 | 11. | 9.2 | 0.28 | + 5 to +23 | + 3 to +28 |
| 10 | 1,076 | 1.2 | 10.9 | 1.1 | 10.2 | 7.5 | 0.23 | 0 to +17 | + 1 to +25 |
| 5 | 1,116 | 1.05 | 9.8 | 0.95 | 8.8 | 5.8 | 0.18 | — 6 to + 9 | — 8 to +14 |
| 5 | 1,080 | 0.65 | 6.35 | 0.6 | 5.9 | 4.8 | 0.17 | —28 to —38 | —23 to —37 |
| 2 | 1,036 | 0.4 | 3.65 | 0.4 | 3.5 | 3.9 | 0.13 | —54 to —62 | —53 to —61 |
| Ave. | 1,055 | 1.41 | 10.58 | 1.34 | 10.1 | 12.25 | 0.42 | — 5 to — 9 | + 6 to —14 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,055 pounds.. | 0.739 | 8.37 | 0.739 | 8.37 | 0.628 | 6.84 |
| Milk, 12.25 pounds, 3½%.. | 0.600 | 3.83 | 0.747 | 3.91 | 0.760 | 3.70 |
| Total maintenance and milk (calculated) .......... | 1.339 | 12.2 | 1.486 | 12.28 | 1.388 | 10.54 |
| Total maintenance and milk (actual) .............. | 1.41 | 10.58 | 1.41 | 10.58 | 1.41 | 10.58 |
| ± ...................... | +5 | —13 | —5 | —14 | +2 | 0 |
| Armsby (conv.) standard.. | 1.29 | 1.41 | + 9% | 9.98 | 10.58 | + 6% |

Lanta 2nd's ration for eight weeks was scanty (—⅛ to —3/10, —3/10 to —4/10). No wonder she shrank heavily in milk yield as is indicated above and gave only 3,888 pounds milk and 132 pounds fat in 10½ months, or 12.25 and 0.42 pounds daily. Her ration was increased at the end of two months but too late to keep her at her best and she placed the surplus food on her back rather than in the pail. Her average ration was from —1/20 deficient to +1/10 excessive in respect to digestible protein and from 1/20 high to 1/7 low in respect to total digestible nutrients. She lost flesh—5 percent—during the third month, regained it and forged ahead, weighing at the end of eight and one-half months 10 percent more than at the end of the third month. However, reduced to a very small food intake during the last seven weeks, she lost most of what she had gained.

V. 14. NESBIT, grade Jersey, five years old, was in milk for 282 days subsequent to calving and dried off while farrow, December 22, 1912 to October 2, 1913. She was fed the high protein ration in succeeding weeks as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 5 | 10. | 30. | 8. | 5 | 8. | 30. | 6. |
| 10 | 10. | 30. | 8.8 | 10 | 8. | 30. | 4.7 |
| 5 | 9. | 30. | 7.2 | 5 | 8. | 30. | 3. |

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 5 | 906 | 2.35 | 14.15 | 2.6 | 15.6 | 25.3 | 1.11 | — 1 to +13 | —16 to + 3 |
| 10 | 935 | 2.6 | 14.9 | 2.75 | 15.9 | 16.4 | 0.88 | +36 to +54 | — 3 to +24 |
| 5 | 957 | 2.25 | 13.25 | 2.35 | 13.85 | 13.2 | 0.72 | +33 to +52 | 0 to +20 |
| 5 | 961 | 1.9 | 12.05 | 2. | 12.55 | 10.6 | 0.66 | +27 to +40 | — 4 to +15 |
| 10 | 979 | 1.65 | 11.2 | 1.7 | 11.5 | 7.7 | 0.45 | +26 to +46 | — 1 to +21 |
| 5 | 1,024 | 1.25 | 9.9 | 1.2 | 9.7 | 2.5 | 0.15 | +36 to +58 | + 7 to +30 |
| Ave. | 960 | 2.03 | 12.7 | 2.14 | 13.3 | 12.45 | 0.66 | +26 to +44 | — 1 to +20 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 960 pounds.. | 0.672 | 7.61 | 0.672 | 7.61 | 0.571 | 6.22 |
| Milk, 12.45 pounds, 5¼%... | 0.772 | 5.12 | 0.934 | 5.20 | 0.952 | 5.13 |
| Total maintenance and milk (calculated) .......... | 1.444 | 12.73 | 1.606 | 12.81 | 1.523 | 11.35 |
| Total maintenance and milk (actual) .............. | 2.03 | 12.7 | 2.03 | 12.7 | 2.03 | 12.7 |
| ± ...................... | +41 | 0 | +26 | —1 | +33 | +12 |
| Armsby (conv.) standard.. | 1.411 | 2.03 | +44% | 10.61 | 12.7 | +20% |

Nesbit had enough to eat except perhaps during the first month, when her total digestible nutrient intake was deficient from 0 to ⅙. Her digestible protein intake (+¼ to +3/7) was much above that which was needed and her total digestible nutrient intake sufficient (0 to +⅕); yet she gave only 3,539 pounds of milk and 188 pounds of fat, less than 90 pounds of milk a week. During 35 weeks she gained slowly in weight and during the last five weeks rapidly, finishing the 40-week feeding period weighing 13 percent more than she did at the outset. Nesbit made flesh rather than milk.

V. 15. NESBIT, grade Jersey, 10 years old, was in milk 168 days, subsequent to calving and prior to service, April 10 to September 24, 1918. Her weight data are lacking for reasons heretofore mentioned (pages 11-12). She was well fed, the high protein ration being used. Her feeding record was:

| Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. | Weeks | Hay<br>lbs. | Silage<br>lbs. | Grain<br>lbs. |
|---|---|---|---|---|---|---|---|
| 3 | 10.1 | 20. | 5.9 | 6 | 15. | 34. | 4.5 |
| 4 | 15. | 32. | 9. | 11 | 9. | 18.4 | 5.1 |

It seems safe to assume that her food intake on the 1,000 pounds live weight basis closely approximated that of the similar record (V. 14) made five years previous.

Assuming that her average live weight was 950 pounds—which perhaps may be somewhat low of truth especially in the latter half of the period—her actual average digestible protein intake was 1.95 and per 1,000 pounds of live weight 2.05 pounds, while her average actual and relative total digestible nutrient intakes were respectively 13.8 and 14.5 pounds. Her food intake, milk and fat yields and comparison data follow:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. | Digestible protein<br>lbs. | Total digestible nutrients<br>lbs. |
| Maintenance, 950 pounds.. | 0.665 | 7.53 | 0.665 | 7.53 | 0.565 | 6.15 |
| Milk, 10.45 pounds, 4¾%.. | 0.611 | 4.02 | 0.741 | 4.11 | 0.747 | 3.90 |
| Total maintenance and milk (calculated) .......... | 1.276 | 11.55 | 1.406 | 11.64 | 1.312 | 10.05 |
| Total maintenance and milk (actual) .............. | 1.95 | 13.8 | 1.95 | 13.8 | 1.95 | 13.8 |
| ± ..................... | +53 | +19 | +39 | +17 | +49 | +38 |
| Armsby (conv.) standard.. | 1.234 | 1.95 | +58% | 9.58 | 13.8 | +44% |

Nesbit had plenty to eat (+⅖ to +⅗, +⅙ to +3/7), certainly after the end of the third week; but she did not do much with what she received unless she put it on her back, for she made only 1,760 pounds of milk and 85 pounds of fat or less than 75 pounds of milk a week and only a half pound of fat a day. However, close deductions cannot be drawn, owing to the loss of the weight data.

V. 16. NESBIT, grade Jersey, 12 years old, was in milk 362 days subsequent to calving and went dry while farrow, July 2, 1919 to June 29, 1920. Her high protein ration was modified from time to time, being essentially as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 8 | 10. | 19. | 5.7 | 3 | 8.5 | 17. | 5. |
| 5 | 12. | 24. | 7. | 6 | 7. | 14. | 4. |
| 6 | 13. | 27. | 8. | 3 | 6.5 | 13. | 3.6 |
| 5 | 9. | 18. | 5.4 | 5 | 8.5 | .. | 4.7 |
| 10 | 10. | 20. | 6. | | | | |

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 8 | 994 | 2.2 | 13.5 | 2.2 | 13.6 | 18.5 | ... | + 8 to +22 | —12 to + 6 |
| 5 | 963 | 2.1 | 13.85 | 2.2 | 14.4 | 13.1 | ... | +28 to +57 | + 7 to +29 |
| 6 | 981 | 2.2 | 13.8 | 2.25 | 14.1 | 9.4 | ... | +60 to +83 | +18 to +44 |
| 5 | 1,038 | 2. | 12.6 | 1.95 | 12.1 | 7.2 | ... | +60 to +83 | +13 to +37 |
| 10 | 1,037 | 1.85 | 11.6 | 1.8 | 11.1 | 5.3 | ... | +66 to +91 | +12 to +36 |
| 3 | 1,033 | 1.6 | 9.85 | 1.55 | 9.55 | 3.6 | ... | +62 to +88 | + 2 to +24 |
| 6 | 1,055 | 1.25 | 8.05 | 1.2 | 7.65 | 3.5 | ... | +26 to +46 | —17 to 0 |
| 3 | 966 | 1.15 | 7.35 | 1.2 | 7.55 | 2.8 | ... | +31 to +52 | —16 to + 2 |
| 5 | 928 | 1.4 | 8. | 1.5 | 8.6 | 2.5 | ... | +69 to +95 | — 4 to +17 |
| Ave. | 1,004 | 1.79 | 11.3 | 1.79 | 11.3 | 8.05 | ... | +39 to +59 | + 1 to +22 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,004 pounds.. | 0.703 | 7.96 | 0.703 | 7.96 | 0.597 | 6.50 |
| Milk, 8.05 pounds, 5%*.... | 0.483 | 3.20 | 0.588 | 3.26 | 0.595 | 3.13 |
| Total maintenance and milk (calculated) .......... | 1.186 | 11.16 | 1.291 | 11.22 | 1.192 | 9.63 |
| Total maintenance and milk (actual) .............. | 1.79 | 11.3 | 1.79 | 11.3 | 1.79 | 11.3 |
| ± ...................... | +51 | +1 | +39 | +1 | +50 | +17 |
| Armsby (conv.) standard.. | 1,128 | 1.79 | +59% | 9.25 | 11.4 | +22% |

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ssumed on basis of her record at other times. No analyses were made.

Nesbit's average food intakes, both actual and relative, were 1.79 pounds digestible protein and 11.3 pounds total digestible nutrients; but she yielded so little milk that this gave her enough to eat. Her digestible protein and total digestible nutrient intakes averaged respectively from ⅖ to ⅗ and from 0 to ⅕ high of standard requirements; yet she gave only 2,901 pounds of milk and a daily average of eight pounds. Her live weight record, however, paralleled her food intake record. During the first quarter of the year when she got from ⅒ to 4/7 more digestible protein than she needed but from ⅛ too little to ¼ too much total digestible nutrients, she dropped 3 percent in live weight coincident with sharp shrinkage in milk flow. During the second three months, making less than half as much milk, while fed an excess of food (+⅗ to +⅞ digestible protein, +⅛ to +⅖ total digestible nutrients) she regained what she lost and at the close had gained 7 percent in live weight. This gain she clung to while shrinking heavily in milk flow, until during the last two months while fed from ⅓ to 9/10 too much digestible protein, but from ⅙ too little to ⅐ too much total digestible nutrients, and making only 3 pounds of milk a day, she shrank greatly in live weight for some reason which was not clear, losing 9 percent in eight weeks. Whatever the cause, probably ill health, it was temporary since the cow later on, on a not over liberal diet, reestablished her normal weight.

Nesbit was never a good cow. She was retained only because of the exigencies of the experiment.

Treating these records in segregated fashion, that is to say, treating each cow as a unit, regardless of how much or how little she ate or made, we have three groups as follows:

I. Four grade Holsteins; in milk when served. (Altje, Bontje [2], Durtje.)

II. Five grade Jerseys; in milk when served. (Hazel K. [2], Jane, Sabra, Nesbit.)

III. Seven farrow grade Jerseys and one farrow registered Ayrshire (Hazel K., Jane, Sabra, Evelyn, Lanta 2nd, Nesbit [2]).

| | Name | Group | Ration | Days | Live weight | Actual | | Per 1,000 pounds | | Milk | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | | | |
| | | | | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| V. 1. | Altje | I | Med. | 76 | 1,245 | 2.55 | 17.1 | 2.05 | 13.7 | 35. | 4.30 | 1.17 |
| V. 2. | Bontje | I | Low | 154 | 1,211 | 2.09 | 20.77 | 1.73 | 17.2 | 34.6 | 4.07 | 1.12 |
| V. 3. | Bontje | I | Low | 99 | 1,085 | 1.53 | 13.3 | 1.41 | 12.25 | 25. | 2.75 | 0.69 |
| V. 4. | Durtje | I | High | 232 | 1,290 | 3.33 | 18.8 | 2.58 | 14.6 | 31.8 | 3.88 | 1.08 |
| V. 5. | Hazel K. | III | Low | 327 | 984 | 1.55 | 15.85 | 1.59 | 16.2 | 14.4 | 2.10 | 0.74 |
| V. 6. | Hazel K. | II | Low | 189 | 957 | 1.67 | 15.25 | 1.75 | 15.9 | 19.6 | 2.96 | 1.06 |
| V. 7. | Hazel K. | II | Low | 56 | 894 | 1.56 | 14. | 1.74 | 15.7 | 24.3 | 3.42 | 1.13 |
| V. 8. | Jane | III | High | 335 | 794 | 2.02 | 12.35 | 2.55 | 15.6 | 12.15 | 1.85 | 0.68 |
| V. 9. | Jane | II | High | 173 | 851 | 2.6 | 16.1 | 3.06 | 19. | 25. | 3.58 | 1.21 |
| V. 10. | Sabra | III | Med. | 329 | 887 | 1.82 | 15. | 2.05 | 16.9 | 10.55 | 1.70 | 0.67 |
| V. 11. | Sabra | II | Med. | 160 | 863 | 2.12 | 14.85 | 2.46 | 17.2 | 20.1 | 3.00 | 1.09 |
| V. 12. | Evelyn | III | Low | 213 | 1,032 | 1.58 | 14.9 | 1.53 | 14.4 | 16.8 | 2.34 | 0.69 |
| V. 13. | Lanta 2nd | III | Med. | 316 | 1,055 | 1.41 | 10.58 | 1.34 | 10.1 | 12.25 | 1.40 | 0.42 |
| V. 14. | Nesbit | III | High | 282 | 960 | 2.03 | 12.7 | 2.14 | 13.3 | 12.45 | 1.86 | 0.66 |
| V. 15. | Nesbit | II | High | 168 | 950* | 1.95 | 13.8 | 2.05 | 14.5 | 10.45 | 1.44 | 0.50 |
| V. 16. | Nesbit | III | High | 362 | 1,004 | 1.79 | 11.3 | 1.79 | 11.3 | 8.05 | 1.16 | 0.41 |
| Average | | | | 217 | 1,004 | 1.98 | 14.8 | 1.99 | 14.9 | 19.5 | 2.61 | 0.83 |
| Group I | | | | 140 | 1,208 | 2.38 | 17.5 | 1.95 | 14.45 | 31.6 | 3.75 | 1.02 |
| Group II | | | | 150 | 903 | 1.98 | 14.8 | 2.21 | 16.45 | 19.9 | 2.88 | 0.99 |
| Group III | | | | 309 | 959 | 1.74 | 13.25 | 1.85 | 14. | 12.4 | 1.77 | 0.61 |
| Low protein fed cows | | | | 173 | 1,027 | 1.66 | 15.7 | 1.63 | 15.3 | 22.5 | 2.91 | 0.91 |
| Medium protein fed cows | | | | 220 | 1,038 | 1.97 | 14.4 | 1.97 | 14.5 | 19.7 | 2.60 | 0.84 |
| High protein fed cows | | | | 259 | 974 | 2.29 | 14.2 | 2.36 | 14.7 | 16.1 | 2.30 | 0.76 |

*Hypothetical.

COMPARISON WITH STANDARDS

| | Entire lot (16 records) | | Group I (4 records) | | Group II (5 records) | | Group III (7 records) | |
|---|---|---|---|---|---|---|---|---|
| Average live weights, lbs. | 1,004 | | 1,208 | | 903 | | 959 | |
| Average digestible protein and total digestible nutrients intakes, lbs. | 1.98 | 14.8 | 2.38 | 17.5 | 1.98 | 14.8 | 1.74 | 13.25 |
| Average digestible protein and total digestible nutrients intakes (Haecker), lbs. | 1.78 | 14.91 | 2.36 | 18.94 | 1.84 | 15.13 | 1.41 | 12.50 |
| Average digestible protein and total digestible nutrients intakes (Savage), lbs. | 2.02 | 15.03 | 2.70 | 19.08 | 2.09 | 15.27 | 1.57 | 12.55 |
| Average digestible protein and total digestible nutrients intakes (Eckles, converted), lbs. | 1.94 | 13.36 | 2.64 | 16.83 | 2.02 | 13.74 | 1.49 | 11.12 |
| Average digestible protein and total digestible nutrients intakes (Armsby, converted), lbs. | 1.77 | 12.37 | 2.38 | 15.48 | 1.85 | 12.66 | 1.38 | 10.40 |
| ± (Haecker) | +11 | — 1 | + 1 | —8 | +8 | —2 | +23 | + 6 |
| ± (Savage) | — 2 | — 2 | —12 | —8 | —5 | —3 | +11 | + 6 |
| ± (Eckles—converted) | + 2 | +11 | —10 | +4 | —2 | +8 | +17 | +19 |
| ± (Armsby—converted) | +12 | +20 | 0 | +13 | +7 | +17 | +26 | +28 |

NOTE.—Entire group 4¼ percent milk; Groups I, II, and III, respectively, 3¼, 5 and 5 percent milks.

COMPARISON WITH STANDARDS

| | Entire lot (16 records) | | Low protein (6 records) | | Medium protein (4 records) | | High protein (6 records) | |
|---|---|---|---|---|---|---|---|---|
| Average live weight, lbs. | 1,004 | | 1,027 | | 1,038 | | 974 | |
| Average digestible protein and total digestible nutrients intakes, lbs. | 1.98 | 14.8 | 1.66 | 15.7 | 1.97 | 14.4 | 2.29 | 14.2 |
| Average digestible protein and total digestible nutrients intakes (Haecker), lbs. | 1.78 | 14.9 | 1.78 | 14.95 | 1.93 | 15.85 | 1.63 | 13.95 |
| Average digestible protein and total digestible nutrients intakes (Savage), lbs. | 2.02 | 15.1 | 2.02 | 15.05 | 2.19 | 16.1 | 1.84 | 14.05 |
| Average digestible protein and total digestible nutrients intakes (Eckles, converted), lbs. | 1.94 | 13.4 | 1.95 | 13.55 | 2.12 | 14.25 | 1.76 | 12.45 |
| Average digestible protein and total digestible nutrients intakes (Armsby, converted), lbs. | 1.77 | 12.35 | 1.77 | 12.4 | 1.93 | 13.1 | 1.62 | 11.6 |
| ± (Haecker) | | | —20 | — 2 | +16 | — 2 | +64 | + 4 |
| ± (Savage) | | | —35 | — 3 | + 1 | — 3 | +41 | + 3 |
| ± (Eckles—converted) | | | —31 | +17 | + 5 | + 8 | +52 | +24 |
| ± (Armsby—converted) | | | —20 | +30 | +15 | +19 | +68 | +36 |

The grade Holsteins as a class during nearly four months of lactation immediately following calving ate too little food (0 to ⅛ deficiency in digestible protein, ⅛ excess to 1/12 deficiency in total digestible nutrients). The grade Jerseys in milk for five months immediately following calving ate barely enough food (0 to 1/12 excess digestible protein, 0 to ⅙ excess total digestible nutrients). The grade Jerseys in milk for 10 months and going dry while farrow ate more than enough digestible protein (1/10 to ¼ excess) as well as enough total digestible nutrients (1/16 to 3/10 excess). As a whole the cows ate enough digestible protein (0 to +⅙) and total digestible nutrients (0 to ⅕).

The cows which made the least ate the most in proportion to production as appear in the subjoined table. Of course it will not do to press such a comparison far, since factors other than the mere food intake contribute to the result, e. g., breed, length of milking period, etc.

| | Total digestible nutrients | Milk | Total solids | Fat | Per pound digestible nutrients Milk | Total solids | Fat |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Group III. Farrow cows in milk 10 months | 13.25 | 12.4 | 1.77 | 0.61 | 0.93 | .133 | .046 |
| Group II. Grade Jerseys in milk 5 months | 14.8 | 19.9 | 2.88 | 0.99 | 1.35 | .196 | .067 |
| Group I. Grade Holsteins in milk 5 months | 17.5 | 31.6 | 3.75 | 1.02 | 1.81 | .214 | .058 |

The grade Holsteins (Group I) which were fed the most heavily but at best ate a bare sufficiency of food, made nearly ⅗ more milk and $\frac{3}{10}$ more total solids than the grade Jerseys (Group II) and $\frac{1}{3}$ and $\frac{1}{10}$ more, respectively, per unit of food intake; but they hardly held their own in respect to live weight.

The grade Jerseys (Group II) were fed very slightly better according to their weight than were the cows in Group I, and made $\frac{2}{5}$ less milk and $\frac{1}{4}$ less total solids on $\frac{1}{6}$ less food, equivalent to $\frac{1}{4}$ less milk and nearly $\frac{1}{10}$ less total solids per unit of food intake, and they gained slightly in live weight.

The farrow cows (Group III) fed the least, but really fed the most in view of their restricted yields—which were due to their long test period, the entire lactation rather than its first five months—averaged to make as compared with the grade Jerseys of Group II about $\frac{3}{5}$ as much milk, total solids and fat and $\frac{2}{3}$ as much per unit of food eaten, and they gained on the average 8 percent in live weight. They made weight full more than milk, as is commonly the case with farrow cows during the latter portion of their milking periods.

The low protein cows were $\frac{1}{5}$ (H., A.) to $\frac{1}{3}$ (S., E.) underfed in respect to digestible protein, but were fed standard amounts (H., S.) and $\frac{1}{6}$ or $\frac{3}{10}$ superstandard amounts (E., A.) of digestible dry matter.

The medium protein cows were fed standard amounts (S., E.) or $\frac{1}{6}$ super-standard amounts (H., A.) of digestible protein and standard amounts (H., S.), $\frac{1}{12}$ and $\frac{1}{5}$ super-standard amounts (E., A.) of digestible dry matter.

The high protein fed cows were fed $\frac{2}{5}$ (S.), $\frac{1}{2}$ (E.), or $\frac{2}{3}$ (H., A.) too much digestible protein and standard (H., S.), $\frac{1}{4}$ or $\frac{3}{8}$ super-standard amounts (E., A.) of digestible dry matter.

The cows on low and on high protein rations respectively were underfed and overfed with digestible protein, while the cows on the medial ration had enough. All received standard (H., S.) or super-standard (E., A.) amounts of total digestible nutrients.

The low and medium protein groups run reasonably true to form, but the high protein group is a joke. The high protein fed cows on the average ate the most digestible protein but the least digestible dry matter and made the smallest amount of milk solids and fat; and yet their nutrient consumption was greatly super-standard. According to standards, the cows thus fed should have eaten from 10 to 20 percent less digestible protein than those fed the low and medium protein rations; yet they ate 20 to 40 percent more. This anomalous situation is due to the fact that three of the six records were furnished by a single cow, a decidedly inferior individual; and one of the other three is a very low record.

## VI. MAINTENANCE AND LACTATION FOR MORE THAN 12 MONTHS

Twelve cows—five grade Holsteins and 10 grade Jerseys—contribute testimony to this phase of the study, three of them twice, making in all 15 records. Ten records are complete, five, owing to the loss of weight records, incomplete. Hazel K. should also have furnished data, but having been turned out to pasture through misunderstanding, her 18 months' record is valueless.

VI. 1. ALTJE, grade Holstein, six years old, was in milk for 522 days subsequent to calving, July 6, 1907 to December 10, 1908, being fed the medium protein ration. She went dry while farrow. Her feeding varied somewhat as is shown below:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 16 | 31.5 | 3. | 10.2 | 12 | 24. | .. | 7.3 |
| 15 | 15.8 | 32.4 | 10. | 8 | 9. | 24. | 3.7 |
| 24 | 17.7 | 29.6 | 7.6 | | | | |

Her food intakes, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 16 | 1,298 | 3.05 | 22.4 | 2.35 | 17.3 | 31.6 | 1.08 | + 8 to +24 | +10 to +35 |
| 15 | 1,335 | 2.6 | 19.9 | 1.95 | 14.9 | 26.6 | 0.88 | + 2 to +19 | + 4 to +32 |
| 24 | 1,317 | 2.3 | 18.4 | 1.75 | 13.95 | 22.1 | 0.77 | + 1 to +16 | + 5 to +29 |
| 12 | 1,238 | 2.15 | 17.15 | 1.75 | 13.85 | 17.7 | 0.65 | +10 to +27 | +11 to +36 |
| 8 | 1,250 | 1.3 | 11.85 | 1.05 | 9.5 | 8.3 | 0.26 | — 7 to +12 | — 6 to +18 |
| Ave. | 1,297 | 2.38 | 18.65 | 1.84 | 14.35 | 22.45 | 0.78 | + 3 to +20 | + 6 to +31 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,297 pounds.. | 0.908 | 10.28 | 0.908 | 10.28 | 0.772 | 8.40 |
| Milk, 22.45 pounds, 3½%.. | 1.100 | 7.03 | 1.370 | 7.16 | 1.392 | 6.78 |
| Total maintenance and milk (calculated) .......... | 2.008 | 17.31 | 2.278 | 17.44 | 2.164 | 15.18 |
| Total maintenance and milk (actual) .............. | 2.38 | 18.65 | 2.38 | 18.65 | 2.38 | 18.65 |
| ± ..................... | +19 | +8 | +4 | +7 | +10 | +23 |
| Armsby (conv.) standard.. | 1.984 | 2.38 | +20% | 14.17 | 18.65 | +32% |

Altje had plenty to eat. The plus signs are always in sight. Her average surplusage in food intakes were: digestible protein, 1/25 to 1/5, total digestible nutrients, 1/14 to 1/3. She made a fair amount of milk, considering the length of the period—nearly a year and a half—22.45 pounds milk, 0.78 pounds fat. She gained 2 percent in live weight during the first year but lost it all and 2 percent more during the last six months, being somewhat less bountifully fed.

VI. 2. ALTJE, grade Holstein, 11 years old, was in milk for 516 days subsequent to calving, September 7, 1912 to February 5, 1914, being fed the medium protein ration. She went dry while farrow. Her feeding was reasonably uniform, though curtailed somewhat as lactation advanced, as is shown below:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 10 | 10.7 | 40. | 10.8 | 15 | 10. | 40. | 5.2 |
| 10 | 10. | 40. | 9.5 | 19 | 10. | 40. | 3.9 |
| 5 | 10. | 40. | 7. | 14 | 10. | 30. | 2.2 |

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 10 | 1,295 | 2.7 | 17.4 | 2.1 | 13.4 | 31.4 | 1.05 | — 4 to +12 | —14 to + 8 |
| 10 | 1,293 | 2.4 | 16.45 | 1.85 | 12.65 | 21.5 | 0.70 | + 8 to +27 | — 4 to +21 |
| 5 | 1,285 | 1.95 | 14.95 | 1.5 | 11.65 | 16.7 | 0.57 | + 2 to +17 | — 4 to +19 |
| 15 | 1,245 | 1.7 | 13.85 | 1.35 | 11.05 | 14.1 | 0.49 | — 2 to +13 | — 4 to +19 |
| 19 | 1,240 | 1.4 | 12.65 | 1.15 | 10.25 | 9.4 | 0.33 | — 3 to +13 | — 1 to +21 |
| 14 | 1,233 | 1.05 | 10.45 | 0.85 | 8.55 | 6.1 | 0.22 | — 1 to —15 | —11 to + 9 |
| Ave. | 1,257 | 1.73 | 13.75 | 1.37 | 10.9 | 14.9 | 0.51 | — 3 to +11 | — 6 to +15 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,257 pounds.. | 0.880 | 9.97 | 0.880 | 9.97 | 0.748 | 8.14 |
| Milk, 14.9 pounds, 3½%... | 0.730 | 4.66 | 0.909 | 4.75 | 0.924 | 4.50 |
| Total maintenance and milk (calculated) .......... | 1.6 | 14.63 | 1.789 | 14.72 | 1.672 | 12.64 |
| Total maintenance and milk (actual) ............. | 1.73 | 13.75 | 1.73 | 13.75 | 1.73 | 13.75 |
| ± ........................ | +7 | —6 | —3 | —7 | +4 | +9 |
| Armsby (conv.) standard.. | 1.553 | 1.73 | +11% | 11.97 | 13.75 | +15% |

Altje seems to have eaten enough digestible protein at all times but her total digestible nutrient consumption during the first two and the last three months was on the borderline of insufficiency. On the average, however, she ate from 1/33 deficiency to 1/8 excess of digestible protein, while her total digestible nutrient intake was from 1/14 too scanty to 1/7 over-plentiful, according to which standard is used as a yardstick. Her milk and fat yields, 14.9 and 0.51 pounds respectively, were fairly good considering the length of the lactation. She shrank continually in live weight, losing 5 percent.

VI. 3. BONTJE, grade Holstein, seven years old, was in milk for 448 days subsequent to calving, January 1, 1909 to March 24, 1910, being fed the low protein ration. She went dry when farrow. Her feeding was curtailed as lactation advanced, as appears below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 30 | 15. | 40. | 12. | 10 | 15. | 36.7 | 8.9 |
| 13 | 15. | 40. | 9.7 | 4 | 10. | 20. | 4. |
| 3 | 15. | 20. | 9.1 | 4 | 13. | 8. | 0. |

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual: Digestible protein | Actual: Total digestible nutrients | Per 1,000 pounds live weight: Digestible protein | Per 1,000 pounds live weight: Total digestible nutrients | Actual: Milk yield | Actual: Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 30 | 1,150 | 2.4 | 23.2 | 2.1 | 20.2 | 38.1 | 1.24 | — 9 to —21 | +12 to +39 |
| 13 | 1,131 | 2.3 | 20.4 | 2.05 | 18.1 | 25.4 | 0.92 | — 2 to +13 | +20 to +47 |
| 3 | 1,116 | 2. | 16.8 | 1.8 | 15. | 25.9 | 0.87 | — 2 to —15 | — 2 to +24 |
| 10 | 1,170 | 2.2 | 18.7 | 1.85 | 16. | 26. | 0.95 | — 8 to + 5 | + 7 to +28 |
| 4 | 1,082 | 1.05 | 10.5 | 0.95 | 9.7 | 18.7 | 0.76 | —39 to —46 | —15 to —31 |
| 4 | 993 | 0.65 | 6. | 0.65 | 6. | 10.4 | 0.39 | —45 to —52 | —23 to —38 |
| Ave | 1,134 | 2.13 | 19.8 | 1.86 | 17.35 | 30.1 | 1.03 | — 6 to —19 | + 7 to +31 |

| | Haecker: Digestible protein | Haecker: Total digestible nutrients | Savage: Digestible protein | Savage: Total digestible nutrients | Eckles (converted): Digestible protein | Eckles (converted): Total digestible nutrients |
|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,134 pounds.. | 0.794 | 8.99 | 0.794 | 8.99 | 0.675 | 7.35 |
| Milk, 30.1 pounds, 3½%... | 1.475 | 9.42 | 1.836 | 9.60 | 1.866 | 9.09 |
| Total maintenance and milk (calculated) .......... | 2.269 | 18.41 | 2.63 | 18.59 | 2.541 | 16.44 |
| Total maintenance and milk (actual) ............. | 2.13 | 19.8 | 2.13 | 19.8 | 2.13 | 19.8 |
| ± ......................... | —6 | +8 | —19 | +7 | —16 | +20 |
| Armsby (conv.) standard.. | 2.3 | 2.13 | — 8% | 15.09 | 19.8 | +31% |

Bontje was stinted, so far as digestible protein was concerned, especially during the first seven months and the last two months, when her ration was short in this respect by 1/10 to 1/5 and by 2/5 to 1/2. However, her total digestible nutrient intake was more than was needed except in the final months when the shortages ranged from 1/7 to 3/8. On the average, her digestible protein consumption failed to be standard by from 1/20 to 1/5, while that of total digestible nutrients was superstandard by from 1/14 to 3/10. Her milk and fat yields were good considering the length of time she was under test—14 months—being 30.1 and 1.03 pounds respectively. She lost in weight quite heavily, weighing at the close 14 percent less than during the mean of the first half of the trial. She maintained her milk flow to some extent at her own proper expense.

VI. 4. BONTJE, grade Holstein, 10 years old, was in milk for 495 days subsequent to calving, April 19, 1912 to the date of service, August 26, 1913, being fed the low protein ration, which was not very greatly varied, except as to its concentrate content, as appears below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|
| 15 | 12. | 29.8 | 11.4 |
| 11 | 12. | 30. | 9. |
| 5 | 10.2 | 30. | 8. |
| 20 | 10. | 36. | 7.6 |
| 20 | 10. | 36. | 6.5 |

Her food intake, milk and fat yields and comparison data follow:

| | | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | Live weight | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 15 | 1,154 | 2. | 17.1 | 1.75 | 14.85 | 38.6 | 1.22 | —25 to —35 | + 1 to —18 |
| 11 | 1,194 | 1.75 | 15.9 | 1.45 | 13.3 | 24.1 | 0.83 | —13 to —24 | — 7 to +15 |
| 5 | 1,172 | 1.5 | 13.8 | 1.25 | 11.85 | 20.2 | 0.72 | —16 to —27 | —12 to + 8 |
| 20 | 1,177 | 1.5 | 14.4 | 1.25 | 12.15 | 20.3 | 0.74 | —16 to —29 | —11 to +12 |
| 20 | 1,164 | 1.4 | 13.7 | 1.2 | 11.75 | 16.6 | 0.61 | —13 to —25 | — 7 to +15 |
| Ave. | 1,171 | 1.63 | 15. | 1.4 | 12.8 | 23.7 | 0.82 | —18 to —28 | —11 to +10 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,171 pounds.. | 0.820 | 9.29 | 0.820 | 9.29 | 0.697 | 7.59 |
| Milk, 23.7 pounds, 3½%... | 1.161 | 7.42 | 1.446 | 7.56 | 1.469 | 7.16 |
| Total maintenance and milk (calculated) .......... | 1.981 | 16.71 | 2.266 | 16.85 | 2.166 | 14.75 |
| Total maintenance and milk (actual) .............. | 1.63 | 15. | 1.63 | 15. | 1.63 | 15. |
| ± ....................... | —18 | —10 | —28 | —11 | —25 | +2 |
| Armsby (conv.) standard.. | 1.977 | 1.63 | —18% | 13.68 | 15. | +10% |

The minus sign is in evidence almost everywhere. Bontje was underfed as regards digestible protein on the average from ⅙ to 3⁄10 and she ate from 1⁄10 too little to 1⁄10 too much total digestible nutrients according to the standard employed. She did very well under the circumstances to make an average 500-day record of 23.7 pounds milk and 0.82 pounds fat. And she maintained and, if anything, increased her live weight, the average for the last five months as compared with that for the first four months being one percent higher.

VI. 5. DURTJE, grade Holstein, five years old, was in milk for 517 days subsequent to calving, from July 5, 1907 to December 3, 1908, being fed the high protein ration. She went dry while farrow. Her ration was changed more often than that of any other cow in any one of the many experimental trials, more frequently than was necessary. However, the story is told below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 1 | 21. | 8. | 5.1 | 10 | 14. | 40. | 8.8 |
| 2 | 31.3 | ... | 10.1 | 1 | 15.4 | 30. | 7.6 |
| 6 | 36. | ... | 12. | 9 | 23. | ... | 7.3 |
| 5 | 42. | ... | 13.5 | 3 | 12. | 48. | 7. |
| 1 | 36. | 15. | 13.5 | 1 | 12.5 | 14. | 5.3 |
| 3 | 24.3 | 37. | 13.4 | 2 | 8.1 | 35.3 | 4.9 |
| 14 | 18. | 33.7 | 13.2 | 3 | 10.1 | 24. | .. |
| 12 | 16.7 | 40. | 9.1 | 1 | 8. | 12.5 | 5. |

Her long statement of food intakes, of milk and fat yields and her comparison data follows:

| Duration | Live weight | Actual |  | Per 1,000 pounds live weight |  | Actual |  | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield |  |  |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 1 | 1,186 | 2.1 | 15.1 | 1.75 | 12.75 | 30.4 | 1.06 | — 9 to —22 | — 3 to —21 |
| 2 | 1,218 | 3.3 | 22.3 | 2.7 | 18.3 | 41.4 | 1.44 | — 2 to +15 | —14 to + 6 |
| 6 | 1,261 | 3.8 | 24.5 | 3. | 19.45 | 40.7 | 1.25 | +19 to +36 | +13 to +39 |
| 5 | 1,274 | 4.8 | 27.5 | 3.8 | 21.6 | 38.1 | 1.16 | +57 to +79 | +31 to +61 |
| 1 | 1,266 | 4.55 | 28.6 | 3.6 | 22.6 | 37.7 | 1.26 | +46 to +69 | +34 to +64 |
| 3 | 1,283 | 4.25 | 27. | 3.3 | 21.1 | 38. | 1.32 | +32 to +54 | +21 to +50 |
| 14 | 1,273 | 3.7 | 21.8 | 2.9 | 17.1 | 33. | 1.08 | +31 to +49 | + 8 to +34 |
| 12 | 1,275 | 3.2 | 19.9 | 2.5 | 15.6 | 26.5 | 0.94 | +28 to +46 | + 7 to +32 |
| 10 | 1,280 | 2.85 | 18.2 | 2.25 | 14.2 | 23.6 | 0.79 | +25 to +42 | + 5 to +30 |
| 1 | 1,288 | 2.85 | 17. | 2.2 | 13.2 | 23.9 | 0.80 | +23 to +41 | + 3 to +27 |
| 9 | 1,190 | 2.5 | 17.3 | 2.1 | 14.55 | 18.9 | 0.63 | +28 to +47 | +14 to +41 |
| 3 | 1,187 | 2.85 | 20.2 | 2.4 | 17. | 13.8 | 0.50 | +71 to +96 | +46 to +80 |
| 1 | 1,214 | 2. | 13.25 | 1.65 | 10.95 | 12.7 | 0.47 | +21 to +40 | — 4 to +17 |
| 2 | 1,240 | 1.8 | 14.2 | 1.45 | 11.45 | 9.3 | 0.32 | +25 to +45 | +11 to +37 |
| 3 | 1,238 | 0.65 | 10. | 0.55 | 8.05 | 5. | 0.11 | —34 to —42 | —11 to +10 |
| 1 | 1,207 | 1.7 | 10.2 | 1.4 | 8.45 | 3.2 | 0.07 | +67 to +95 | — 2 to +20 |
| Ave. | 1,254 | 3.18 | 20.2 | 2.53 | 16.1 | 27.1 | 0.91 | +29 to +47 | +11 to +37 |

|  | Haecker |  | Savage |  | Eckles (converted) |  |
|---|---|---|---|---|---|---|
|  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
|  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,254 pounds.. | 0.878 | 9.94 | 0.878 | 9.94 | 0.746 | 8.13 |
| Milk, 27.1 pounds, 3¼%... | 1.301 | 8.10 | 1.599 | 8.21 | 1.653 | 7.90 |
| Total maintenance and milk (calculated) .......... | 2.179 | 18.04 | 2.477 | 18.15 | 2.399 | 16.03 |
| Total maintenance and milk (actual) ............. | 3.18 | 20.2 | 3.18 | 20.2 | 3.18 | 20.2 |
| ± ....................... | +46 | +12 | +28 | +11 | +33 | +26 |
| Armsby (conv.) standard.. | 2.169 | 3.18 | +47% | 14.74 | 20.2 | +37% |

Durtje was well fed except during the first week and three weeks at the very close when she was put upon a restricted ration in order to dry her off. She received a great excess of digestible protein and more than enough total digestible nutrients. The surplusages ranged from 1/5 to 9/10 in digestible protein and from 1/12 to 3/4 in total digestible nutrients. The average super-standard ration carried from 3/10 to nearly 1/2 too much digestible protein and from 1/8 to 3/8 too much total digestible nutrients. Durtje responded well to such treatment and averaged during more than 17 months 27.1 pounds of milk and 0.91 pounds of fat. She gained in weight rapidly at the outset and held her gains for a year, being at its close 9 percent heavier than at the outset. She then rapidly fell off and during two months lost it all, then began to regain and had added 4 percent to her live weight when, following three weeks of low feeding, she dropped most of it, closing the long trial weighing 2 percent more than at the beginning.

VI. 6. SABRA, grade Jersey, 10 years old, was in milk for 379 days subsequent to calving, from September 29, 1912 to October 15, 1913, when she was sold while still in milk, being barren. She was fed the medium protein ration and her feeding was reasonably uniform as appears below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|
| 7 | 10. | 30. | 8. |
| 20 | 10. | 30. | 9. |
| 5 | 9. | 30. | 8. |
| 21 | 8. | 30. | 6.3 |
| 1 | 6.3 | 24. | 4.4 |

Her food intake, milk and fat yields and comparison data follow:

| | | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | Live weight | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 7 | 902 | 2. | 14.05 | 2.25 | 15.65 | 20.2 | 1.30 | — 3 to —15 | —1 to —17 |
| 20 | 878 | 2.2 | 14.95 | 2.5 | 17. | 19.9 | 1.16 | — 1 to +13 | —3 to + 9 |
| 5 | 851 | 2. | 13.9 | 2.35 | 16.4 | 16.5 | 0.97 | + 3 to +18 | —3 to +16 |
| 21 | 834 | 1.65 | 12.1 | 2. | 14.5 | 12.3 | 0.78 | + 3 to +15 | —4 to +16 |
| 1 | 880 | 1.2 | 9.05 | 1.35 | 10.25 | 5.7 | 0.34 | +12 to +35 | —6 to +14 |
| Ave. | 862 | 1.93 | 13.5 | 2.24 | 15.7 | 16.45 | 0.99 | — 6 to +13 | — 2 to +13 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 862 pounds... | 0.604 | 6.84 | 0.604 | 6.84 | 0.514 | 5.59 |
| Milk, 16.45 pounds, 6%.... | 1.102 | 7.42 | 1.332 | 7.52 | 1.364 | 8.00 |
| Total maintenance and milk (calculated) .......... | 1.706 | 14.26 | 1.936 | 14.36 | 1.878 | 13.59 |
| Total maintenance and milk (actual) .............. | 1.93 | 13.5 | 1.93 | 13.5 | 1.93 | 13.5 |
| ± ....................... | +14 | —5 | 0 | —6 | +3 | 0 |
| Armsby (conv.) standard.. | 1.713 | 1.93 | +13% | 12.01 | 13.5 | +13% |

Sabra was not liberally treated at the outset. During the first half of the year her total digestible nutrient intake ranged from —1/6 to +1/10 according to the standard and her digestible protein intake from —1/7 to +1/8. During the second half her total digestible nutrient intake varied from barely standard (—1/25) to 1/6 excess, and she ate from 1/33 to 1/3 excess of digestible protein. The average figures for the entire period are: digestible protein, 0 to 1/7 excess; total digestible nutrients, 1/8 excess to 1/20 deficiency. She made fair yields, 16.45 and 0.99 pounds of milk and fat respectively, but fell off in live weight though gaining again at the end. The net loss between the mean figures for the first one and a half months and the last five months is 7 percent. Sabra could not both make milk and maintain her live weight on her food intake; hence she lost in weight.

VI. 7. DELL R., grade Ayrshire, four years old, was in milk for 487 days subsequent to calving, from May 3, 1913 to September 5, 1914, drying off when farrow. She was fed the high protein ration. Her digestible protein intake was cut considerably as lactation advanced, more than was proportionately total digestible nutrient intake; but she always had enough and to spare. Her feeding statement follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 2 | 8. | 29.8 | 7.5 | 20 | 8. | 25. | 4.2 |
| 26 | 8. | 25. | 8.6 | 5 | 8. | 21. | 2.9 |
| 15 | 8. | 25. | 6.2 | 1 | 8. | * | 2. |

*25 pounds green millet.

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 2 | 795 | 2.2 | 13.15 | 2.75 | 16.5 | 26.3 | 1. | 0 to +15 | —13 to + 7 |
| 26 | 816 | 2.4 | 12.85 | 2.95 | 15.75 | 23.7 | 0.91 | +16 to +34 | —11 to + 6 |
| 15 | 902 | 1.9 | 11.3 | 2.1 | 12.5 | 14.7 | 0.56 | +24 to +40 | — 5 to +15 |
| 20 | 964 | 1.5 | 10.1 | 1.55 | 10.55 | 11.2 | 0.43 | + 9 to +23 | —11 to + 7 |
| 5 | 958 | 1.2 | 8.8 | 1.25 | 9.2 | 6.4 | 0.24 | +12 to +29 | —10 to +11 |
| 1 | 918 | 1.2 | 9.8 | 1.3 | 10.7 | 2.4 | 0.09 | +51 to +27 | +11 to +48 |
| Ave. | 889 | 1.93 | 11.4 | 2.21 | 13. | 16.65 | 0.63 | +16 to +32 | —10 to +11 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 889 pounds... | 0.622 | 7.04 | 0.622 | 7.04 | 0.530 | 5.77 |
| Milk, 16.65 pounds, 3¾%.. | 0.858 | 5.47 | 1.050 | 5.58 | 1.058 | 5.22 |
| Total maintenance and milk (calculated) .......... | 1.48 | 12.51 | 1.672 | 12.62 | 1.588 | 10.99 |
| Total maintenance and milk (actual) .............. | 1.93 | 11.4 | 1.93 | 11.4 | 1.93 | 11.4 |
| ± ...................... | +30 | —9 | +16 | —10 | +21 | +4 |
| Armsby (conv.) standard.. | 1.461 | 1.93 | +32% | 10.3 | 11.4 | +11% |

Dell R. ate plenty of digestible protein but barely enough total digestible nutrients. There was not much change in her diet as regards total digestible nutrients as the trial advanced. She was always kept on the ragged edge. On the average she ate from 1/6 to 1/3 too much digestible protein and from 1/10 too little to 1/10 too much total digestible nutrients. She made 16.65 pounds milk and 0.63 pounds fat on the average for almost 500 days and gained very heavily in live weight, her average live weight for the first seven, the mid-four and the last six months being respectively 814, 902 and 961 pounds, the latter figure being 18 percent higher than the first. In other words, she made weight full more than milk although her milk yield, in view of her youth and low plane of nutrition, was not a poor one.

VI. 8. EFFA, grade Jersey, five years old, was in milk for 492 days subsequent to calving, from June 4, 1913 to October 15, 1914, going dry while farrow. She was fed the low protein ration and her feeding was on the whole quite uniform as appears below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 1 | 8. | 25. | 7. | 1 | 8. | * | 3. |
| 17 | 8. | 25. | 7.9 | 3 | 12. | 14. | 4. |
| 40 | 8. | 25. | 6.3 | 3 | 14. | .. | 4. |
| 5 | 8. | 20. | 4.6 | | | | |

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 1 | 757 | 1.2 | 11.1 | 1.6 | 14.6 | 21. | 1.23 | —33 to —42 | —23 to — 8 |
| 17 | 755 | 1.4 | 12.35 | 1.85 | 16.35 | 17.2 | 0.94 | —14 to —24 | — 8 to +11 |
| 40 | 813 | 1.2 | 11.2 | 1.5 | 13.8 | 13.5 | 0.84 | —19 to —29 | —12 to + 5 |
| 5 | 832 | 1.05 | 10. | 1.25 | 12. | 11.9 | 0.77 | —25 to —34 | —19 to — 3 |
| 1 | 770 | 0.9 | 9.5 | 1.15 | 12.35 | 8.6 | 0.54 | —18 to —28 | — 6 to + 1 |
| 3 | 786 | 1.1 | 10.7 | 1.4 | 13.6 | 7.7 | 0.52 | —10 to + 2 | + 7 to +28 |
| 3 | 781 | 1.1 | 9.75 | 1.4 | 12.45 | 4.1 | 0.29 | +20 to +38 | +18 to +42 |
| Ave. | 796 | 1.23 | 11.3 | 1.54 | 14.1 | 13.7 | 0.82 | —17 to —26 | —10 to + 8 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 796 pounds... | 0.557 | 6.31 | 0.557 | 6.31 | 0.474 | 5.16 |
| Milk, 13.7 pounds, 6%..... | 0.918 | 6.18 | 1.110 | 6.26 | 1.137 | 6.66 |
| Total maintenance and milk (calculated) .......... | 1.475 | 12.49 | 1.667 | 12.57 | 1.611 | 11.82 |
| Total maintenance and milk (actual) .............. | 1.23 | 11.3 | 1.23 | 11.3 | 1.23 | 11.3 |
| ± ...................... | —17 | —10 | —26 | —10 | —24 | —4 |
| Armsby (conv.) standard.. | 1.474 | 1.23 | —17% | 10.5 | 11.3 | + 8% |

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*25 pounds green millet.

Effa was considerably underfed in respect to her digestible protein intake. Only during the last three of the 71 weeks did she get a sufficiency. And at best she ate barely enough total digestible nutrients. On the average Effa consumed from ⅛ to ¼ too little digestible protein and from 1/10 too little to 1/12 too much total digestible nutrients. She made a fair milk and fat yield record for 492 days, namely 13.7 and 0.82 pounds. She increased in live weight, weighing 8 percent more during the mid-45 weeks than during the initial 18 weeks; but half this gain was lost during the last seven weeks, although her food intake was not lowered.

VI. 9. MARY, grade Jersey, four years old, was in milk for 826 days subsequent to calving, from May 17, 1912 to August 20, 1914, when she went dry while farrow. She was fed the medium protein ration, which naturally was varied somewhat during her prolonged lactation—as is indicated below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|
| 1* | 8.6 | 25.2 | 2.1 |
| 1* | 1. | 15. | 4. |
| 9* | ... | 15. | 8. |
| 11 | 6.5 | 15. | 9. |
| 10 | 10. | 30. | 8.5 |
| 10 | 10. | 30. | 6.6 |
| 30 | 8.5 | 30. | 4.7 |
| 38 | 8. | 25.5 | 3.4 |
| 8 | 8. | 24.1 | 2.5 |

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*Through error Mary was pastured during the first seven weeks.

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 1 | .... | 1.05* | 9.1* | 1.05 | 9.1 | 16.9 | 0.73 | —30 to —43 | —12 to —36 |
| 1 | .... | 0.85* | 5. * | 0.85 | 5. | 32.7 | 1.44 | —67 to —71 | —53 to —76 |
| 9 | 1,001 | 1.45* | 7.1* | 1.45 | 7.1 | 30.9 | 1.49 | —42 to —53 | —57 to —64 |
| 11 | 984 | 1.95 | 11.1 | 2. | 11.3 | 24.8 | 1.26 | —10 to —22 | —25 to —37 |
| 10 | 952 | 2.2 | 14.4 | 2.35 | 15.2 | 18.4 | 0.93 | +10 to +24 | — 4 to +16 |
| 10 | 974 | 1.8 | 13.35 | 1.85 | 13.75 | 13.9 | 0.74 | + 4 to +19 | — 1 to +19 |
| 30 | 1,008 | 1.4 | 10.95 | 1.4 | 10.85 | 10.5 | 0.55 | — 7 to + 7 | —11 to + 7 |
| 38 | 1,029 | 1.1 | 9.55 | 1.05 | 9.35 | 7.7 | 0.43 | — 4 to —16 | + 1 to —17 |
| 8 | 1,034 | 1. | 8.95 | 0.95 | 8.65 | 5.3 | 0.30 | + 2 to —12 | + 4 to —15 |
| Ave. | 1,006 | 1.42* | 10.5* | 1.42* | 10.5* | 13.3 | 0.69 | — 5 to —17 | — 6 to —22 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,006 pounds.. | 0.704 | 7.99 | 0.704 | 7.99 | 0.598 | 6.51 |
| Milk, 13.3 pounds, 5¼%... | 0.825 | 5.47 | 0.998 | 5.56 | 1.017 | 5.47 |
| Total maintenance and milk (calculated) .......... | 1.529 | 13.46 | 1.702 | 13.55 | 1.615 | 11.98 |
| Total maintenance and milk (actual) .............. | 1.42* | 10.5* | 1.42* | 10.5* | 1.42* | 10.5* |
| ± ........................ | —7 | —22 | —17 | —22 | —12 | —12 |
| Armsby (conv.) standard.. | 1.496 | 1.42* | — 5% | 11.2 | 10.5* | — 6% |

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*Does not include the food eaten during seven weeks of pasturage. All food intake figures affected.

Mary's record, so far as feeding is concerned, was a minus one. During only 20 of the 118 weeks is the plus sign really in evidence. Mary undoubtedly was underfed seriously during the first fifth of the long feeding period, but less so later on. The average figures for the entire 27 months are: digestible protein —1/20 to —1/6; total digestible nutrients —1/16 to —1/5. Under such circumstances Mary did well to maintain her milk yield as she did and to average 13.3 pounds milk and 0.69 pounds fat for 27 months. She shrank 5 percent in live weight during the heaviest milking period but more than regained her loss, weighing at the close 3 percent more than when she started.

VI. 10. KARAH, grade Jersey, nine years old, was in milk for 404 days subsequent to calving from May 16, 1919 to June 24, 1920, being fed the low protein ration and going dry while farrow. Her ration was a reasonably constant one as the subjoined record indicates:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 3 | 9.5 | 19. | 5.1 | 13 | 13. | 28.1 | 8.2 |
| 6 | 11.7 | 22.6 | 6.7 | 19 | 11.6 | 23.5 | 6.8 |
| 9 | 9.7 | 25.2 | 7.4 | 8 | 8.5 | 17.5 | 5. |

Her food intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 3 | 787 | 1.1 | 10.5 | 1.4 | 13.3 | 16.6 | ... | —32 to —40 | — 6 to —22 |
| 6 | 775 | 1.35 | 13.2 | 1.75 | 17. | 18.2 | ... | —21 to —30 | — 6 to +13 |
| 9 | 761 | 1.4 | 13. | 1.85 | 17.05 | 12.9 | ... | — 8 to + 4 | +12 to +35 |
| 13 | 806 | 1.65 | 15.5 | 2.05 | 19.3 | 9.4 | ... | +28 to +46 | +49 to +79 |
| 19 | 881 | 1.4 | 13.5 | 1.6 | 15.3 | 6.8 | ... | +23 to +41 | +36 to +65 |
| 8 | 821 | 1. | 10. | 1.2 | 12. | 3.2 | ... | +22 to +41 | +27 to +54 |
| Ave. | 822 | 1.4 | 13.45 | 1.72 | 16.35 | 9.55 | ... | + 7 to +22 | +28 to +53 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 822 pounds... | 0.576 | 6.52 | 0.576 | 6.52 | 0.490 | 5.34 |
| Milk, 9.55 pounds, 5½%*.. | 0.611 | 4.05 | 0.735 | 4.12 | 0.754 | 4.13 |
| Total maintenance and milk (calculated) .......... | 1.187 | 10.57 | 1.311 | 10.64 | 1.244 | 9.47 |
| Total maintenance and milk (actual) ............. | 1.4 | 13.45 | 1.4 | 13.45 | 1.4 | 13.45 |
| ± ........................ | +18 | +27 | +7 | +26 | +13 | +42 |
| Armsby (conv.) standard.. | 1.148 | 1.4 | +22% | 8.82 | 13.45 | +53% |

Karah was underfed at the very outset for about two months but during the remaining year had plenty to eat. The initial shortages were: digestible protein —1/5 to 2/5 total digestible nutrients —1/5 to +1/7. Throughout the rest of her feeding period the surplusages were considerable, being quite enough to more than balance the initial shortages and to bring about an average excess usage as follows: digestible protein +1/14 to +1/5, total digestible nutrients +3/8 to +1/2.

Karah's response was not a good one. She shrank rapidly in milk yield and six months after calving, although farrow and getting much more to eat than her milk yields warranted, she had shrunk one-half in her product, which at no time was large. Her average for the 14 months—9.55 pounds milk and about a half pound of fat daily—was unsatisfactory. She rapidly increased in live weight after the ration was so changed that minuses became pluses, in six months gaining 16 percent; but she had lost half this gain at the close of the trial.

VI. 11-15. The records of five cows can be used only in a general way, owing to the loss of the weight data heretofore referred to (pages 11-12). They were grade Jerseys and went dry when farrow. The data, in so far as they are available, follow:

| Weeks | Hay | Silage | Grain | Digestible protein | Total digestible nutrients | Milk | Fat | Weeks | Hay | Silage | Grain | Digestible protein | Total digestible nutrients | Milk | Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| **VI. 11. Augusta, 820 pounds, four years old, fed high protein ration 414 days, May 8, 1915 to July 6, 1916** | | | | | | | | | | | | | | | |
| 1 | 10.3 | 29.3 | 7.3 | 2.2 | 14.2 | 27.1 | 1.26 | 5 | 9. | 18. | 5. | 1.55 | 10.8 | 9.6 | 0.55 |
| 6 | 12. | 25. | 9.3 | 2.85 | 16. | 25.8 | 1.14 | 5 | 9. | 18. | 3.6 | 1.25 | 9.85 | 8.5 | 0.53 |
| 10 | 12. | 25. | 7.7 | 2.6 | 15.1 | 17. | 0.75 | 5 | 7. | 14. | 3.8 | 1.2 | 8.4 | 7.9 | 0.49 |
| 12 | 12. | 25. | 6.2 | 2.25 | 14.2 | 13.1 | 0.71 | 10 | 6. | 12. | 3. | 1. | 7.05 | 7.2 | 0.42 |
| 5 | 10.4 | 20. | 5.8 | 2. | 12.25 | 10.3 | 0.60 | Ave. | | | | 1.92 | 12.1 | 13. | 0.66 |
| **VI. 12. Fizzy, 900 pounds, two years old, fed high protein ration 545 days, November 4, 1914 to May 4, 1916** | | | | | | | | | | | | | | | |
| 1* | 10. | 20.7 | 2.4 | 1.15 | 8.85 | 29. | 1.51 | 10 | 10.1 | 21.2 | 6.2 | 2.1 | 12.5 | 12.3 | 0.71 |
| 1 | 10. | 30.6 | 8.4 | 2.45 | 13.2 | 26.9 | 1.40 | 7 | 10. | 20.9 | 4.8 | 1.7 | 10.55 | 7.4 | 0.40 |
| 2 | 12. | 32. | 10.1 | 3.05 | 17.35 | 28.9 | 1.49 | 15 | 8. | 18. | 3.9 | 1.35 | 9.4 | 7.5 | 0.45 |
| 10 | 12. | 26.4 | 10.6 | 3.15 | 17.05 | 25.2 | 1.38 | 5 | 8. | 18. | 2.4 | 0.95 | 8.6 | 6.3 | 0.41 |
| 10 | 12. | 25. | 8.5 | 2.65 | 15.35 | 20.7 | 1.21 | 8 | 7. | 15. | ... | 0.35 | 5.9 | 2.1 | 0.14 |
| 10 | 11.1 | 24.1 | 6.7 | 2.25 | 13.65 | 18.5 | 1.07 | Ave. | | | | 1.91 | 12. | 13.7 | 0.79 |
| **VI. 13. Isadore, 890 pounds, eight years old. fed medium protein ration 411 days, June 3, 1915 to July 20, 1916** | | | | | | | | | | | | | | | |
| 1 | 11.7 | 26. | 3.9 | 1.4 | 11.9 | 16.3 | 0.72 | 5 | 9.9 | 21. | 6. | 1.45 | 12.5 | 10.5 | 0.68 |
| 3 | 12. | 25. | 6.2 | 1.8 | 13.7 | 22.8 | 1.04 | 16 | 10. | 21. | 4.1 | 1.15 | 10.4 | 9.2 | 0.63 |
| 5 | 12. | 25. | 8.1 | 2. | 14.8 | 19.4 | 0.98 | 7 | 10. | 21. | ... | 0.75 | 8.7 | 5.5 | 0.30 |
| 12 | 12. | 25. | 6.4 | 1.75 | 13.9 | 15.4 | 0.78 | Ave. | | | | 1.5 | 12.45 | 12.45 | 0.71 |
| 10 | 12. | 25. | 7.6 | 1.95 | 14.5 | 13.1 | 0.81 | | | | | | | | |
| **VI. 14. Vinegar, 890 pounds, four years old, fed medium protein ration 434 days, April 1, 1915 to June 8, 1916** | | | | | | | | | | | | | | | |
| 1* | 10. | 36. | 2.7 | 1.25 | 12.8 | 33.8 | 1.60 | 5 | 9.1 | 20.4 | 4.6 | 1.3 | 10.6 | 7.9 | 0.51 |
| 2 | 10. | 36. | 9.2 | 2.35 | 16.9 | 30.9 | 1.48 | 11 | 8. | 18. | 3.2 | 0.9 | 9.1 | 5.5 | 0.38 |
| 5 | 10. | 30. | 9.4 | 2.35 | 15.1 | 28.6 | 1.42 | 3 | 7. | 14. | 2.2 | 0.7 | 7.25 | 4.8 | 0.33 |
| 5 | 11.6 | 26.1 | 9.6 | 2.4 | 15.9 | 22.7 | 1.16 | 8 | 7. | 14. | ... | 0.35 | 5.8 | 3.1 | 0.21 |
| 5 | 12. | 25. | 7.6 | 2. | 14.6 | 17.8 | 0.92 | Ave. | | | | 1.45 | 11.4 | 12.6 | 0.68 |
| 17 | 10. | 22. | 6.7 | 1.7 | 12.6 | 11.8 | 0.68 | | | | | | | | |
| **VI. 15. Karah, 850 pounds, five years old, fed low protein ration 495 days, January 15, 1915 to May 25, 1916** | | | | | | | | | | | | | | | |
| 1* | 10. | 36. | 2.7 | 1.05 | 10.2 | 27.5 | 1.40 | 10 | 11. | 22. | 6.5 | 1.4 | 12.9 | 12. | 0.68 |
| 3 | 9.3 | 36. | 9.2 | 1.7 | 15.8 | 27.9 | 1.43 | 9 | 10. | 20. | 5.2 | 1.05 | 11.65 | 11.1 | 0.64 |
| 10 | 12. | 25. | 9.6 | 1.8 | 15.8 | 25.8 | 1.33 | 12 | 8.2 | 18. | ... | 0.45 | 7.5 | 5. | 0.31 |
| 10 | 12. | 25. | 7.9 | 1.6 | 14.8 | 21.3 | 1.11 | Ave. | | | | 1.33 | 13.05 | 15.8 | 0.85 |
| 17 | 12. | 25. | 7.1 | 1.55 | 14.3 | 16. | 0.85 | | | | | | | | |

*Three days only.

Attention is called to the fact that the live weights are hypothetical and approximate but, also, to the great care employed in determining them (see pages 11-12).

The following statements set forth the data in so far as they pertain to these cows:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VI. 11. Augusta | | | | | | |
| Maintenance, 820 pounds... | 0.574 | 6.50 | 0.574 | 6.50 | 0.488 | 5.31 |
| Milk, 13. pounds, 5%...... | 0.780 | 5.17 | 0.949 | 5.27 | 0.962 | 5.06 |
| Total maintenance and milk (calculated) .......... | 1.354 | 11.67 | 1.523 | 11.77 | 1.450 | 10.37 |
| Total maintenance and milk (actual) .............. | 1.92 | 12.1 | 1.92 | 12.1 | 1.92 | 12.1 |
| ± ...................... | +42 | +4 | +26 | +3 | +32 | +17 |
| Armsby (conv.) standard.. | 1.346 | 1.92 | +43% | 9.73 | 12.1 | +24% |
| VI. 12. Fizzy | | | | | | |
| Maintenance, 900 pounds... | 0.630 | 7.14 | 0.630 | 7.14 | 0.536 | 5.83 |
| Milk, 13.7 pounds, 5¾%.... | 0.897 | 5.99 | 1.082 | 6.08 | 1.110 | 6.29 |
| Total maintenance and milk (calculated) .......... | 1.527 | 13.13 | 1.712 | 13.22 | 1.646 | 12.22 |
| Total maintenance and milk (actual) .............. | 1.91 | 12. | 1.91 | 12. | 1.91 | 12. |
| ± ...................... | +25 | —9 | +12 | —9 | +16 | —2 |
| Armsby (conv.) standard.. | 1.509 | 1.91 | +26% | 11.10 | 12. | +8% |
| VI. 13 Isadore | | | | | | |
| Maintenance, 890 pounds.. | 0.623 | 7.06 | 0.623 | 7.06 | 0.530 | 5.77 |
| Milk, 12.45 pounds, 5¾%.. | 0.817 | 5.45 | 0.984 | 5.51 | 1.008 | 5.73 |
| Total maintenance and milk (calculated) .......... | 1.440 | 12.51 | 1.607 | 12.57 | 1.538 | 11.50 |
| Total maintenance and milk (actual) .............. | 1.5 | 12.4 | 1.5 | 12.4 | 1.5 | 12.4 |
| ± ...................... | +4 | —1 | —7 | —1 | —2 | +8 |
| Armsby (conv.) standard.. | 1.414 | 1.5 | +6% | 10.48 | 12.4 | +18% |
| VI. 14. Vinegar | | | | | | |
| Maintenance, 890 pounds... | 0.623 | 7.06 | 0.623 | 7.06 | 0.530 | 5.77 |
| Milk, 12.6 pounds, 5½%... | 0.806 | 5.34 | 0.970 | 5.43 | 0.995 | 5.44 |
| Total maintenance and milk (calculated) .......... | 1.429 | 12.40 | 1.593 | 12.49 | 1.525 | 11.21 |
| Total maintenance and milk (actual) .............. | 1.45 | 11.4 | 1.45 | 11.4 | 1.45 | 11.4 |
| ± ...................... | +1 | —8 | —9 | —9 | —5 | +2 |
| Armsby (conv.) standard.. | 1.399 | 1.45 | +3% | 10.37 | 11.4 | +10% |
| VI. 15. Karah | | | | | | |
| Maintenance, 850 pounds... | 0.595 | 6.74 | 0.595 | 6.74 | 0.505 | 5.51 |
| Milk, 15.8 pounds, 5½%.... | 1.011 | 6.70 | 1.217 | 6.81 | 1.248 | 6.83 |
| Total maintenance and milk (calculated) .......... | 1.606 | 13.44 | 1.812 | 13.55 | 1.753 | 12.34 |
| Total maintenance and milk (actual) .............. | 1.33 | 13.05 | 1.33 | 13.05 | 1.33 | 13.05 |
| ± ...................... | —17 | —3 | —27 | —4 | —24 | +6 |
| Armsby (conv.) standard.. | 1.596 | 1.33 | —17% | 11.28 | 13.05 | +16% |

So far as digestible protein is concerned Augusta and Fizzy, on the high protein ration, were fed respectively from $\frac{1}{4}$ to $\frac{3}{7}$ and from $\frac{1}{8}$ to $\frac{1}{4}$ excess; Isadore and Vinegar receiving the medium protein ration, respectively from $\frac{1}{16}$ excess to $\frac{1}{4}$ deficiency and from $\frac{1}{33}$ excess to $\frac{1}{10}$ deficiency; while Karah, who ate the low protein ration, lacked from $\frac{1}{6}$ to $\frac{1}{4}$ of eating enough to meet standard requirements.

None of the cows received a surplus of total digestible nutrients except as measured by the Armsby (converted) standard, the figures being: Augusta $+\frac{1}{33}$ to $+\frac{1}{4}$; Fizzy, 0 to $+\frac{1}{12}$; Isadore, 0 to $+\frac{1}{5}$; Vinegar, $+\frac{1}{10}$ to $-\frac{1}{10}$; Karah, $-\frac{1}{38}$ to $+\frac{1}{6}$.

The milk and fat yields in view of the restricted diets were fairly satisfactory, being: Augusta, 13. and 0.66; Fizzy, 13.7 and 0.79; Isadore, 12.45 and 0.71; Vinegar, 12.3 and 0.68; Karah, 15.8 and 0.85.

Treating these 15 records in segregated fashion, each cow being treated as a unit regardless of how much or how little she ate or gave, we have three groups, as follows:

I. Four grade Holsteins, farrow when dried off (Altje (2), Bontje, Durtje).

II. One grade Holstein, in milk when served (Bontje).

III. Ten grade Jerseys and one grade Ayrshire, all but one farrow when dried off, one (Sabra) giving 5.7 pounds a day when sold (Sabra, Dell R., Effa, Mary, Karah (2), Augusta, Fizzy, Isadore, Vinegar).

| Section and number | | Name | Group | Ration | Days | Live weight | Actual | | Per 1,000 pounds | | Milk | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | | | |
| | | | | | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VI. | 1. | Altje | I | Med. | 522 | 1,297 | 2.38 | 18.65 | 1.84 | 14.35 | 22.45 | 2.75 | 0.78 |
| VI. | 2. | Altje | I | Med. | 516 | 1,257 | 1.73 | 13.75 | 1.37 | 10.8 | 14.9 | 1.73 | 0.51 |
| VI. | 3. | Bontje | I | Low | 448 | 1,134 | 2.13 | 19.8 | 1.86 | 17.35 | 30.1 | 3.54 | 1.03 |
| VI. | 4. | Bontje | II | Low | 495 | 1,171 | 1.63 | 15. | 1.40 | 12.8 | 23.7 | 2.86 | 0.82 |
| VI. | 5. | Durtje | I | High | 517 | 1,254 | 3.18 | 20.2 | 2.53 | 16.1 | 27.1 | 3.22 | 0.91 |
| VI. | 6. | Sabra | III | Med. | 379 | 862 | 1.93 | 13.5 | 2.24 | 15.7 | 16.45 | 2.54 | 0.99 |
| VI. | 7. | Dell R. | III | High | 487 | 889 | 1.93 | 11.4 | 2.21 | 13. | 16.65 | 2.12 | 0.63 |
| VI. | 8. | Effa | III | Low | 492 | 796 | 1.23 | 11.3 | 1.54 | 14.1 | 13.7 | 2.12 | 0.82 |
| VI. | 9. | Mary | III | Med. | 826 | 1,006 | 1.42 | 10.5 | 1.42 | 10.5 | 13.3 | 1.91 | 0.69 |
| VI. | 10. | Karah | III | Low | 404 | 822 | 1.4 | 13.45 | 1.72 | 16.35 | 9.55 | *1.44 | *0.52 |
| VI. | 11. | Augusta | III | High | 414 | 820* | 1.92 | 12.1 | 2.34 | 14.75 | 13. | 1.88 | 0.66 |
| VI. | 12. | Fizzy | III | High | 545 | 900* | 1.91 | 12. | 2.12 | 13.35 | 13.7 | 2.16 | 0.79 |
| VI. | 13. | Isadore | III | Med. | 411 | 890* | 1.5 | 12.45 | 1.69 | 14. | 12.45 | 1.88 | 0.71 |
| VI. | 14. | Vinegar | III | Med. | 434 | 890* | 1.45 | 11.4 | 1.63 | 12.8 | 12,6 | 1.83 | 0.68 |
| VI. | 15. | Karah | III | Low | 495 | 850* | 1.33 | 13.05 | 1.56 | 15.35 | 15.8 | 2.38 | 0.85 |
| Average | | | | | 493 | 988 | 1.81 | 13.9 | 1.83 | 14.1 | 17.05 | 2.29 | 0.76 |
| Group I | | | | | 501 | 1,236 | 2.36 | 18.1 | 1.9 | 14.7 | 23.65 | 2.81 | 0.81 |
| Group II | | | | | 495 | 1,171 | 1.63 | 15. | 1.40 | 12.8 | 23.7 | 2.86 | 0.82 |
| Group III | | | | | 489 | 873 | 1.60 | 12.1 | 1.84 | 14. | 13.7 | 2.03 | 0.73 |
| Low protein | | | | | 467 | 955 | 1.54 | 14.5 | 1.62 | 15.2 | 18.6 | 2.47 | 0.81 |
| Medium protein | | | | | 515 | 1,035 | 1.74 | 13.4 | 1.70 | 13.05 | 15.05 | 2.11 | 0.73 |
| High protein | | | | | 491 | 966 | 2.24 | 13.9 | 2.30 | 14.3 | 18.6 | 2.35 | 0.75 |

*Hypothetical.

COMPARISON WITH STANDARDS

| | Entire lot (15 records) | | Group I (4 records) | | Group II (1 record) | | Group III (10 records) | |
|---|---|---|---|---|---|---|---|---|
| Average live weights, lbs. | 988 | | 1,236 | | 1,171 | | 873 | |
| Average digestible protein and total digestible nutrients intakes, lbs. | 1.81 | 13.9 | 2.36 | 18.1 | 1.63 | 15. | 1.60 | 12.1 |
| Average digestible protein and total digestible nutrients intakes (Haecker), lbs. | 1.66 | 14.1 | 2.02 | 17.10 | 1.98 | 16.71 | 1.48 | 12.64 |
| Average digestible protein and total digestible nutrients intakes (Savage), lbs. | 1.87 | 14.2 | 2.29 | 17.23 | 2.27 | 16.85 | 1.65 | 12.73 |
| Average digestible protein and total digestible nutrients intakes (Eckles, converted), lbs. | 1.79 | 12.7 | 2.19 | 15.07 | 2.17 | 14.75 | 1.58 | 11.55 |
| Average digestible protein and total digestible nutrients intakes (Armsby, converted), lbs. | 1.64 | 11.7 | 2.00 | 13.99 | 1.98 | 13.68 | 1.46 | 10.56 |
| ± (Haecker) | + 9 | — 1 | +17 | + 6 | —18 | —10 | + 8 | —4 |
| ± (Savage) | — 3 | — 2 | + 3 | + 5 | —28 | —10 | — 3 | —5 |
| ± (Eckles, converted) | + 1 | + 9 | + 8 | +20 | —25 | — 2 | + 1 | +5 |
| ± (Armsby, converted) | +10 | +19 | +18 | +29 | —18 | +10 | +10 | +14 |

NOTE.—Entire group 4½ percent milk; Groups I, II and III, respectively, 3½, 3⅛ and 5¼ percent milks.

COMPARISON WITH STANDARDS

| | Entire lot (15 records) | | Low protein (5 records) | | Medium protein (6 records) | | High protein (4 records) | |
|---|---|---|---|---|---|---|---|---|
| Average live weights, lbs. | 988 | | 955 | | 1,035 | | 966 | |
| Average digestible protein and total digestible nutrients intakes, lbs. | 1.81 | 13.9 | 1.54 | 14.5 | 1.74 | 13.4 | 2.24 | 13.9 |
| Average digestible protein and total digestible nutrients intakes (Haecker), lbs. | 1.66 | 14.1 | 1.71 | 14.3 | 1.62 | 14.05 | 1.64 | 13.85 |
| Average digestible protein and total digestible nutrients intakes (Savage), lbs. | 1.88 | 14.2 | 2.02 | 14.4 | 1.82 | 14.2 | 1.85 | 13.95 |
| Average digestible protein and total digestible nutrients intakes (Eckles, converted), lbs. | 1.79 | 12.7 | 1.86 | 12.95 | 1.73 | 12.7 | 1.77 | 12.4 |
| Average digestible protein and total digestible nutrients intakes (Armsby, converted), lbs. | 1.64 | 11.7 | 1.70 | 11.85 | 1.59 | 11.7 | 1.62 | 11.45 |
| ± (Haecker) | +9 | —1 | —8 | +2 | +6 | —6 | +36 | 0 |
| ± (Savage) | —3 | —2 | —19 | +2 | —5 | —6 | +21 | —1 |
| ± (Eckles, converted) | +1 | +9 | —15 | +13 | 0 | +5 | +26 | +11 |
| ± (Armsby, converted) | +10 | +19 | —8 | +24 | +8 | +14 | +37 | +20 |

The grade Holsteins as a class, that is to say, those which dried off while farrow, ate more than enough food (0 to 1/6 excess digestible protein, 1/20 to 3/10 excess total digestible nutrients. Bontje, grade Holstein, the only cow served when in milk, ate far too little (1/5 to 3/10 deficiency in digestible protein, 1/10 deficiency to 1/10 excess, in total digestible nutrients). And the ten cows, mostly farrow when dried off, had enough to eat to meet standard requirements (0 to 1/10 excess digestible protein, 1/20 deficiency to 1/7 excess total digestible nutrients). The entire lot of cows on the average ate standard amounts of digestible protein (0 to +1/10) and total digestible nutrients (0 to +1/5). Indeed it is interesting to note how close is the comparison between the average figures and those in section V (page 90).

| | Haecker | | Savage | | Eckles (converted) | | Armsby (converted) | |
|---|---|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | % | % | % | % | % | % | % | % |
| V. 16 records | +11 | —1 | —2 | —2 | +2 | +11 | +12 | +20 |
| VI. 15 records | +9 | —1 | —3 | —2 | +1 | +9 | +10 | +19 |

As was noted under section V, page 91, the cows which made the most milk (groups I and II) used less food per unit of product in making it than those which yielded less. However, the reverse was true in respect to solids and fat, the cows making the lower milk yields making more solids and fat per food unit than those yielding more heavily.

| | Total digestible nutrients | Milk | Total solids | Fat | Per pound of total digestible nutrients<br>Milk | <br>Total solids | <br>Fat |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Group III. Farrow Jerseys, etc. | 12.1 | 13.7 | 2.03 | 0.73 | 1.13 | .168 | .060 |
| Groups I and II. Farrow Holsteins, etc | 17.5 | 23.65 | 2.82 | 0.81 | 1.35 | .161 | .046 |

The Holsteins, fed enough food, made 3/4 more milk, 2/5 more solids and 1/10 more fat than the Jerseys, using 3/7 more food; and made per unit of food 1/5 more milk but 1/20 less solids and 1/4 less fat. The grade Holsteins as a whole lost weight during the long trial, two decidedly, one slightly, two practically holding their own. The registered Ayrshire added greatly to her live weight, three grade Jerseys increased somewhat in live weight and one lost quite heavily.

The low protein fed cows ate 1/12 too little digestible protein (H., A.) and 1/7 to 1/5 too little (E., S.), but standard (H., S.) to 1/7 to 1/4 superstandard amounts (E., A.) of digestible dry matter.

The medium protein fed cows ate from 1/20 too little (S.) to 1/14 too much (H., A.) digestible protein and from 1/20 too little (H., S.) to 1/7 too much (A.) digestible dry matter.

The high protein fed cows ate from 1/5 to 1/4 too much (S., E.) to 3/8 too much (H., A.) digestible protein and from standard amounts (H., S.) to 1/10 to 1/5 too much (E., A.) digestible dry matter.

## VII. MAINTENANCE AND LACTATION OF NON-PREGNANT COWS WHICH HAD ABORTED

Five cows contribute testimony here, one of them twice. However, owing to prolonged illness, one record of this latter cow is of little avail. There are thus five serviceable records.

VII. 1. ALTJE, grade Holstein, nine years old, was in milk for 133 days following abortion and prior to service, from August 2 to December 13, 1910. She was fed the medium protein ration. Her feeding after the first month was quite uniform as is indicated below:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 4 | 8. | 30. | 8.9 | 11 | 17. | 36. | 9. |
| 4 | 16.3 | 32. | 10. | | | | |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 4 | 1,296 | 2.25 | 15.2 | 1.74 | 11.75 | 36.4 | 1.26 | —15 to —27 | —15 to —[illegible] |
| 4 | 1,330 | 2.9 | 20.3 | 2.18 | 15.3 | 33.8 | 1.12 | — 1 to +14 | — 2 to +[illegible] |
| 11 | 1,344 | 2.65 | 19.4 | 1.97 | 14.45 | 29.6 | 1.01 | — 1 to +12 | — 1 to +1[illegible] |
| Ave. | 1,331 | 2.61 | 18.6 | 1.96 | 14. | 31.85 | 1.09 | — 9 to + 5 | —10 to +1[illegible] |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,331 pounds.. | 0.932 | 10.55 | 0.932 | 10.55 | 0.792 | 8.62 |
| Milk, 31.85 pounds, 3½%... | 1.561 | 9.97 | 1.943 | 10.16 | 1.974 | 9.62 |
| Total maintenance and milk (calculated) .......... | 2.493 | 20.52 | 2.875 | 20.71 | 2.766 | 18.24 |
| Total maintenance and milk (actual) .............. | 2.61 | 18.6 | 2.61 | 18.6 | 2.61 | 18.6 |
| ± ........................ | +5 | —9 | —9 | —10 | —6 | +2 |
| Armsby (conv.) standard.. | 2.512 | 2.61 | +4% | 16.8 | 18.6 | +11% |

Altje received a sub-standard ration or, at the best, barely a standard ration. During the first month she was decidedly underfed. During the next four months, however, she received from 0 to about ⅕ more total digestible nutrients than standards indicated. On the average, her digestible protein intake was from 1/10 deficient to 1/20 excessive and her total digestible nutrient intake from 1/10 deficient to 1/10 excessive. Under the circumstances, in view of her limited ration and her misfortune, Altje did well to make practically 32 pounds of milk and 1.1 pounds of fat daily for five months.

VII. 2. SABRA, grade Jersey, seven years old, was in milk for 138 days from May 25 to October 11, 1910, subsequent to abortion and prior to service. She was fed the medium protein ration. Her food was increased as she progressed in lactation as is indicated below:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 1* | 6. | 8.6 | 2. | 10 | 12. | 25. | 8. |
| 3* | 3.2* | 5.5 | 4.7 | 2 | 12. | 28.6 | 8.6 |
| 2 | 12. | 12.5 | 8. | 2 | 15. | 36. | 8.6 |

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*Pastured during this time.

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual |  | Per 1,000 pounds live weight |  | Actual |  | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield |  |  |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 1 | 798 | 0.7* | 6.* | 0.88* | 7.5* | 15.7 | 0.89 | —56 to —61 | —46 to —55 |
| 3 | 753 | 0.95* | 5.7* | 1.26* | 7.6* | 23.6 | 1.29 | —54 to —60 | —58 to —65 |
| 2 | 794 | 2.05 | 13.8 | 2.58 | 17.4 | 27.5 | 1.39 | — 7 to —20 | — 5 to —21 |
| 10 | 835 | 2.25 | 15.95 | 2.7 | 19.1 | 25. | 1.26 | — 7 to + 8 | — 5 to +15 |
| 2 | 878 | 2.45 | 15.65 | 2.79 | 17.8 | 20.3 | 1.24 | + 8 to +24 | — 4 to +15 |
| 2 | 884 | 2.6 | 18.3 | 2.95 | 20.7 | 17.7 | 1.03 | +29 to +47 | +23 to +48 |
| Ave. | 826 | 2.01 | 13.95 | 2.42 | 16.7 | 23.5 | 1.24 | —14 to — 1 | —15 to + 2 |

|  | Haecker |  | Savage |  | Eckles (converted) |  |
|---|---|---|---|---|---|---|
|  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
|  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 826 pounds... | 0.578 | 6.55 | 0.578 | 6.55 | 0.491 | 5.35 |
| Milk, 23.5 pounds, 5¼%.... | 1.457 | 9.66 | 1.763 | 9.82 | 1.798 | 9.66 |
| Total maintenance and milk (calculated) .......... | 2.035 | 16.21 | 2.341 | 16.37 | 2.289 | 15.01 |
| Total maintenance and milk (actual) ............. | 2.01 | 13.95 | 2.01 | 13.95 | 2.01 | 13.95 |
| ± ....................... | —1 | —14 | —14 | —15 | —12 | —7 |
| Armsby (conv.) standard.. | 2.077 | 2.01 | — 3% | 13.65 | 13.95 | + 2% |

*At pasture three weeks.

Sabra was at pasture for three weeks at the outset, her condition being such that it seemed essential. Of course no record could be kept as to her food intake while in pasture and hence the figures in the subjoined tables for the first two sub-periods are low of truth and, consequently, the averages are understatements. In only two or possibly three instances in the entire set of trials was the strict rule abrogated to keep the animals in the barn and the exercise yards. This was one of these exceptions, made for what at the time appeared to be sufficient reason.

Subject to the qualifications indicated above in connection with the feeding of this cow immediately after abortion when she was at pasture, it may be said that Sabra received a sub-standard ration. Shutting one's eyes to her food intake in the pasture, she ate on the average from 0 to 1/7 too little digestible protein and from 0 to 1/7 too little total digestible nutrients. During the third, fourth and fifth sub-periods, when she was entirely barn fed, she received either a substandard or a more than standard ration, according to the measuring stick which is used. It will be noted, furthermore, that she gave more milk and more fat after she came in from pasture than while she was at pasture. Apparently she utilized her pasture period to some extent in regaining her bodily condition following her misfortune. Under the circumstances Sabra did well to make an average of 23.5 pounds of milk and 1.24 pounds of butter fat during the four and one-half months following abortion.

VII. 3. NESBIT, grade Jersey, eight years old, was in milk for 200 days following abortion, from June 11 to December 30, 1916, at which time she went dry while farrow. She was fed the high protein ration. Her feeding record follows[1]:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 1 | 6. | 8.6 | 2. | 2 | 12. | 12.5 | 8. |
| 1 | .. | 2.9 | 3. | 10 | 12. | 25. | 8. |
| 1 | .. | 5.7 | 5. | 2 | 12. | 28.6 | 8.6 |
| 1 | 9.7 | 8. | 6. | 2 | 15. | 36. | 8.6 |

Owing to the loss of the weight records (see pages 11-12), only the following general statement can be made:

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 960 pounds... | 0.672 | 7.61 | 0.672 | 7.61 | 0.571 | 6.22 |
| Milk, 15.75 pounds, 5%.... | 0.945 | 6.27 | 1.150 | 6.38 | 1.166 | 6.13 |
| Total maintenance and milk (calculated) .......... | 1.617 | 13.88 | 1.822 | 13.99 | 1.737 | 12.35 |
| Total maintenance and milk (actual) .............. | 2.2 | 14.05 | 2.2 | 14.05 | 2.2 | 14.05 |
| ± ........................ | +36 | +1 | +21 | 0 | +27 | +14 |
| Armsby (conv.) standard.. | 1.611 | 2.2 | +37% | 11.57 | 14.05 | +22% |

Owing to the fact that Nesbit was fed the high protein ration and was fed a liberal amount of grain, she naturally received an excessive supply of this nutrient, the excess ranging from +1/5 to +3/8, and she ate from 0 to +1/5 excess of total digestible nutrients. Yet, notwithstanding, she made only 15.75 pounds of milk and 0.79 pounds of fat—a poor record in view of what she received. However, Nesbit, as is elsewhere remarked, was never a good cow.

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[1] There seems reason to assume that Nesbit was pastured for three weeks; yet none of the records indicate it. Her feeding was extremely low, otherwise.

VII. 4. AUGUSTA, grade Jersey, eight years old, was in milk for 146 days from September 13, 1919, when she aborted, until February 6, 1920, when she was sold, unserved, while giving about 12 pounds of milk. She was fed the high protein ration and was treated liberally with a view of keeping her at work, her misfortune to the contrary notwithstanding, as appears by the subjoined feeding record:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 1 | 5.7 | 12. | 3.4 | 4 | 11.3 | 24. | 9. |
| 6 | 11.4 | 24. | 6.8 | 6 | 14. | 28. | 9. |
| 4 | 12.7 | 26.4 | 8.3 | | | | |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | | Total digestible nutrients ± of standards | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | .% | % |
| 1* | 820 | 1.05 | 6.75 | 1.3 | 8.25 | 23.1 | ... | —56 to | — 54 | —49 to | —57 |
| 6 | 738 | 2.15 | 13.45 | 2.9 | 18.2 | 21.2 | ... | + 4 to | + 17 | — 7 to | + 2 |
| 4 | 732 | 2.5 | 15.4 | 3.4 | 21. | 16.2 | ... | +48 to | + 68 | +25 to | +50 |
| 4 | 729 | 2.5 | 14.8 | 3.45 | 20.3 | 15.4 | ... | +53 to | + 75 | +23 to | +49 |
| 6 | 736 | 2.75 | 16.6 | 3.75 | 22.55 | 13.75 | ... | +81 to | +105 | +46 to | +76 |
| Ave. | 737 | 2.41 | 14.65 | 3.27 | 19.9 | 17.1 | ... | +38 to | + 58 | +17 to | +38 |

*Six days.

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 737 pounds... | 0.516 | 5.84 | 0.516 | 5.84 | 0.439 | 4.78 |
| Milk, 17.1 pounds, 5%..... | 1.026 | 6.81 | 1.248 | 6.93 | 1.265 | 6.65 |
| Total maintenance and milk (calculated) .......... | 1.542 | 12.65 | 1.764 | 12.77 | 1.704 | 11.43 |
| Total maintenance and milk (actual) ............. | 2.41 | 14.65 | 2.41 | 14.65 | 2.41 | 14.65 |
| ± ...................... | +56 | +16 | +37 | +15 | +42 | +28 |
| Armsby (conv.) standard.. | 1.554 | 2.41 | +54% | 10.53 | 14.65 | +38% |

No samples were taken of Augusta's milk during this particular period, but in view of the considerable data in hand covering a period of four years it is fairly safe to assume that its average fat content for nearly five months closely approximated 5 percent.

Augusta was grossly overfed. She received from 3/8 to 4/7 more digestible protein and from 1/7 to 3/8 more digestible nutrients than she needed; and yet she made but 17.1 pounds of milk and 0.85 pounds of fat. It would seem as if she should have done better.

VII. 5. ISADORE, grade Jersey, 11 years old, aborted July 5, 1918, served June 12, 1919, was fed the medium protein ration. Her record, which was faithfully kept, is of little or no avail for the reason that, beginning August 3 and continuing for several weeks, the cow was seriously ill.

VII. 6. ISADORE, grade Jersey, 13 years old, aborted on February 13 and dried off on October 19, 1920, being in milk 249 days. She was fed the medium protein ration, her feeding record being as follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 17 | 9. | 18. | 5. | 1 | 15. | 31. | 9. |
| 8 | 10. | 21. | 6. | 4 | 8. | 31. | 9. |
| 4 | 14. | 28. | 8. | 1 | 13. | 28. | 8. |

Her nutrient intake, milk yield and comparison data follow:

| | | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | Live weight | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % |
| 17 | 889 | 1.2 | 10.05 | 1.35 | 11.3 | 16.8 | ... | — 31 to — 40 | —18 to — 32 |
| 8 | 822 | 1.35 | 11.6 | 1.65 | 14.1 | 7.9 | ... | + 11 to + 27 | +15 to + 38 |
| 4 | 827 | 1.85 | 15.8 | 2.25 | 19.1 | 7.9 | ... | + 52 to + 73 | +55 to + 87 |
| 1 | 832 | 2.05 | 17.3 | 2.45 | 20.8 | 5.1 | ... | +106 to +136 | +94 to +134 |
| 4 | 833 | 1.85 | 13.8 | 2.2 | 16.6 | 3.2 | ... | +120 to +153 | +71 to [illegible] |
| 1 | 871 | 1.8 | 15.3 | 2.05 | 17.75 | 2. | ... | +133 to +170 | +96 to +138 |
| Ave. | 858 | 1.43 | 11.85 | 1.67 | 13.8 | 11.4 | ... | — 6 to + 7 | — 1 to + 18 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 858 pounds... | 0.601 | 6.80 | 0.601 | 6.80 | 0.511 | [illegible] |
| Milk, 11.4 pounds, 6%..... | 0.764 | 5.14 | 0.923 | 5.21 | 0.946 | 5.34 |
| Total maintenance and milk (calculated) .......... | 1.365 | 11.94 | 1.524 | 12.01 | 1.457 | [illegible] |
| Total maintenance and milk (actual) ............. | 1.43 | 11.85 | 1.43 | 11.85 | 1.43 | 11.85 |
| ± ...................... | +5 | —1 | —6 | —1 | —2 | +7 |
| Armsby (conv.) standard.. | 1.343 | 1.43 | + 7% | 10.01 | 11.85 | +18 |

Isadore's milk was not analyzed and less data exist as to its quality under similar circumstances than exist in the few other cases where assumptions had to be made. However, there is every reason to believe that it averaged fully 6 percent of fat. She always gave rich milk.

During the first four months she was seriously underfed both in respect to her digestible protein and her total digestible nutrient intakes which were lacking $\frac{3}{10}$ to $\frac{2}{5}$ and $\frac{1}{6}$ to $\frac{1}{3}$ respectively; and she responded by rapidly dropping in live weight. During the next two months she got a more nearly rational diet ($+\frac{1}{10}$ to $+\frac{1}{4}$ digestible protein: $+\frac{1}{7}$ to $+\frac{3}{8}$ total digestible nutrients), and she ceased losing weight. During the next two months, however, notwithstanding liberal feeding ($+\frac{1}{2}$ to $+\frac{6}{4}$ digestible protein; $+\frac{1}{2}$ to $+\frac{6}{4}$ total digestible nutrients), she barely held her own, though beginning to respond at the very close of the period. On the average she ate an almost exact standard diet, except in respect to the Armsby (converted) standard; but in view of the profound changes in her feeding an average does not mean much.

These five records can not be treated as a unit with the same degree of safety as were those located in sections V and VI. Their numbers are less and the history of the cows is very divergent. Furthermore, in one case the live weight is hypothetical and in two instances, since no milk analyses were made, the figures for total solids and fat are hypothetical. While these figures are doubtless close approximations, obviously they are not exact and, in view of the small numbers in the group, naturally these lapses affect the validity of the average. However, it seems advisable to attempt an average, these limitations to the contrary notwithstanding, and the data appear in the subjoined table:

| Section and number | Name | Breed | Ration | Days in milk | At close | Live weight | Actual | | Per 1,000 pounds | | Milk | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | | | |
| | | | | | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VII. 1. | Altje | Gd. Holstein | Med. | 133 | S. | 1,331 | 2.61 | 18.6 | 1.96 | 14. | 31.85 | 3.81 | 1.09 |
| VII. 2. | Sabra | Gd. Jersey | Med. | 138 | S. | 826 | 2.01 | 13.95 | 2.42 | 16.7 | 23.5 | 3.35 | 1.24 |
| VII. 3. | Nesbit | Gd. Jersey | High | 200 | D. | 960* | 2.2 | 14.05 | 2.28 | 14.65 | 15.75 | 2.22 | 0.79 |
| VII. 4. | Augusta | Gd. Jersey | High | 146 | So. | 737 | 2.41 | 14.65 | 3.27 | 19.9 | 17.1 | 2.46* | 0.85* |
| VII. 6. | Isadore | Gd. Jersey | Med. | 249 | D. | 858 | 1.43 | 11.85 | 1.67 | 13.8 | 11.4 | 1.77* | 0.66* |
| Average | | | | 173 | | 942 | 2.13 | 14.65 | 2.32 | 15.8 | 19.9 | 2.71 | 0.93 |
| Medium protein | | | | 173 | | 1,005 | 2.02 | 14.8 | 2.02 | 14.8 | 22.3 | 2.98 | 1.00 |
| High protein | | | | 173 | | 849 | 2.31 | 14.35 | 2.78 | 17.3 | 16.4 | 2.31 | 0.82 |

*Hypothetical. S. = served; D. = dry; So. = sold in milk.

COMPARISON WITH STANDARDS

| | Entire lot (5 records) | | Medium protein (3 records) | | High protein (2 records) | |
|---|---|---|---|---|---|---|
| Average live weights, lbs. | 943 | | 1,005 | | 849 | |
| Average digestible protein and total digestible nutrients intakes, lbs. | 2.14 | 14.6 | 2.02 | 14.8 | 2.31 | 14.35 |
| Average digestible protein and total digestible nutrients intakes (Haecker), lbs. | 1.81 | 15. | 1.97 | 16.2 | 1.58 | 13.25 |
| Average digestible protein and total digestible nutrients intakes (Savage), lbs. | 2.07 | 15.15 | 2.25 | 16.35 | 1.79 | 13.4 |
| Average digestible protein and total digestible nutrients intakes (Eckles, converted), lbs. | 1.99 | 13.65 | 2.17 | 14.8 | 1.72 | 11.9 |
| Average digestible protein and total digestible nutrients intakes (Armsby, converted), lbs. | 1.82 | 12.5 | 1.98 | 13.5 | 1.58 | 11.05 |
| ± (Haecker) | +20 | − 1 | + 3 | − 8 | +46 | + 9 |
| ± (Savage) | + 6 | − 2 | −10 | − 9 | +29 | + 8 |
| ± (Eckles, converted) | +10 | + 9 | − 7 | + 1 | +35 | +21 |
| ± (Armsby, converted) | +20 | +18 | + 3 | +11 | +46 | +30 |

The records of the cows in section VII are to be compared—if at all—not with those of the cows in section VI, which on the average were in milk for 493 days, but with those of the cows in section V which were in milk on the average for 217 days. There were six records made by grade Holsteins and Ayrshires and 10 made by grade Jerseys in group V, whereas in group VII there was only one grade Holstein and five grade Jerseys. Obviously the former group is advantaged as to milk yields in respect to breed characteristics, whereas the latter group is advantaged in respect to the shorter time and consequent heavier average daily flow; yet, on the other hand, it is disadvantaged by the fact that the cows had aborted. On this account it would seem well to make comparisons not only with the average of the 16 records in section V but likewise with the average of five records selected from these 16 records; records of cows in milk for about the same length of time as those in section VII, one of them a grade Holstein and the others grade Jerseys. Consequently a comparison of this character is included in the subjoined table. The three horizontal lines show; first, the average record of the entire 16 cows in group V; second, the record of the selected five cows from group V; and, third, the record of the five cows in group 7.

| Section | Number of records | Days in milk | Live weight | Actual |  | Per 1,000 pounds |  | Milk | Total solids | Fat |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |  |  |  |
|  |  |  | lbs. | lbs. | lbs. | bs. | lbs. | lbs. | lbs. | lbs. |
| V | 16 | 217 | 1,004 | 1.98 | 14.8 | 1.99 | 14.9 | 19.5 | 2.61 | 0.83 |
| V | 5 | 195 | 998 | 2.22 | 15.75 | 2.19 | 15.7 | 20.7 | 2.84 | 0.91 |
| VII | 5 | 173 | 942 | 2.13 | 14.65 | 2.32 | 15.8 | 19.9 | 2.71 | 0.93 |

Comparing the two entire groups, we observe that the cows which aborted ate, per 1,000 pounds live weight, ⅛ more digestible protein and 1/16 more total digestible nutrients than did the cows which calved regularly and that they made a trifle more of considerably richer milk. However, their trial period was considerably shorter than that of their competitors. But when the more comparable average records of the two sets of five cows each are placed side by side it will be observed that the figures are somewhat more closely alike; that the cows which aborted did essentially as well as did those which did not abort. Not that they would do so throughout an entire lactation—far from it—but that in the particular trial under review and during the initial six months of the lactation period, they did about as well as those which did not abort. However, the important point in the present connection is this: that to all intents and purposes and in relation to the question at issue, abortion to the contrary notwithstanding, these five records can be treated on a parity with the 16 records listed in section V in which they naturally would have been included had the cows calved normally.

The medium protein fed cows ate from 1/14 to 1/10 too little (S., E.) or standard amounts (H., A.) of digestible protein and 1/12 too little (H., S.), standard (E.) or 1/9 too much (A.) digestible dry matter.

The high protein fed cows ate 3/10 to 3/8 too much (S., E.) to 4/9 too much (H., S.) digestible dry matter.

The former as a whole were not fed quite enough, the latter too much, according to standards.

## VIII. MAINTENANCE, LACTATION AND FŒTAL CONSTRUCTION

Six cows furnish testimony as to this matter, three of them twice and one thrice. However, in one instance the cow was pastured through error and the record vitiated. Ten records are available.

VIII. 1. ALTJE, grade Holstein, 10 years old, was fed for 278 days from service to calving, December 13, 1910 to September 17, 1911, being dry during the last six weeks of the period. She was fed the medium protein ration. Her feeding record follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 4 | 17. | 36. | 9. | 12 | 12. | 40. | 8.4 |
| 8 | 16.7 | 44. | 9. | 2 | 12. | 40. | 6.3 |
| 3 | 15. | 44. | 8.4 | 1 | 12. | 40. | .. |
| 3 | 15. | 40. | 8.4 | 6 | 12. | 31.7 | .. |

Her nutrient intake, yields and camparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % to % | % to % |
| 4 | 1,362 | 2.5 | 19.5 | 1.85 | 14.3 | 26.4 | 0.90 | — 2 to +11 | —11 to +1 |
| 8 | 1,370 | 2.85 | 19.8 | 2.1 | 14.45 | 25.9 | 0.91 | +12 to +29 | + 4 to +2 |
| 3 | 1,367 | 2.75 | 19.7 | 2. | 14.35 | 25. | 0.92 | + 9 to +24 | + 2 to +2 |
| 3 | 1,389 | 2.7 | 18.6 | 1.95 | 13.4 | 23.8 | 0.87 | + 5 to +25 | — 2 to +2 |
| 12 | 1,408 | 2.5 | 17.5 | 1.8 | 12.4 | 19.1 | 0.72 | +14 to +31 | 0 to +2 |
| 2 | 1,423 | 2. | 15.95 | 1.4 | 11.25 | 9.8 | 0.42 | +21 to +40 | + 7 to +31 |
| 1 | 1,440 | 0.95 | 12.2 | 0.65 | 8.5 | 4.7 | 0.18 | —16 to —27 | — 6 to +14 |
| 6 | 1,433 | 0.85 | 11.3 | 0.6 | 7.9 | Dry | | 0 to —15 | — 1 to +22 |
| Ave. 33 weeks | 1,390 | 2.55 | 18.4 | 1.83 | 13.2 | 21.6 | 0.79 | + 9 to +25 | — 1 to +21 |
| Ave. 39 weeks | 1,397 | 2.29 | 17.25 | 1.63 | 12.35 | 18.25 | 0.67 | + 8 to +24 | — 1 to +22 |

It has seemed necessary in connection with the study of the records in this particular group, to make two final statements, namely, one covering the time when the cow was in milk and one covering the entire gestation, including both the time while she was in milk and when she was dry. This system is followed in each of the ten cases discussed in this particular section of the bulletin.

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,390 pounds.. | 0.973 | 11.02 | 0.973 | 11.02 | 0.827 | 9.01 |
| Milk, 21.6 pounds, 3¾%.... | 1.112 | 7.08 | 1.361 | 7.24 | 1.372 | 6.76 |
| Total maintenance and milk (calculated) .......... | 2.085 | 18.1 | 2.334 | 18.26 | 2.199 | 15.77 |
| Total maintenance and milk (actual) ............. | 2.55 | 18.4 | 2.55 | 18.4 | 2.55 | 18.4 |
| ± ...................... | +22 | +2 | +9 | +1 | +16 | +17 |
| Armsby (conv.) standard.. | 2.037 | 2.55 | +25% | 14.91 | 18.4 | +23% |
| Maintenance, 1,397 pounds.. | 0.978 | 11.09 | 0.978 | 11.09 | 0.833 | 9.06 |
| Milk, 18.25 pounds, 3¾%.. | 0.940 | 5.99 | 1.150 | 6.11 | 1.159 | 5.71 |
| Total maintenance and milk (calculated) .......... | 1.918 | 17.08 | 2.128 | 17.20 | 1.992 | 14.77 |
| Total maintenance and milk (actual) .............. | 2.29 | 17.25 | 2.29 | 17.25 | 2.29 | 17.25 |
| ± ...................... | +19 | +1 | +8 | 0 | +15 | +17 |
| Armsby (conv.) standard.. | 1.855 | 2.29 | +24% | 14.03 | 17.25 | +23% |

Altje, on the whole, had enough to eat. Her digestible protein intake was super-standard. She received from 1/10 to ¼ more digestible protein than standards indicated. Her total digestible nutrient intake, however, was varied from 0 to ⅕ excess. The minus signs are rarely in evidence except during the time when she was dry and the weeks immediately preceding drying off.

Altje had aborted the previous August and had made during the four and one-half months between abortion and service an average of practically 32 pounds of milk a day. Under the circumstances, she did well in the eight months following to make an average of 21.6 pounds of milk and 0.79 pounds of fat. She seems to have had, on the whole, enough to do with.

VIII. 2. ALTJE, grade Holstein, 10 years old, was fed the medium protein ration for 277 days, from December 4, 1911 to September 7, 1912, from service to calving. Her feeding record follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| $5^3/_7$ | 12. | 36. | 10. | 3 | 12. | 40. | 4. |
| 13 | 12. | 40. | 10. | 1 | 12. | 40. | 3. |
| 13 | 12. | 40. | 9. | $4^2/_7$ | 12. | 40. | .. |

Her nutrient intake, yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 5+ | 1,256 | 2.5 | 17.65 | 2. | 14.1 | 30.4 | 0.97 | — 6 to + 8 | — 8 to +13 |
| 13 | 1,271 | 2.55 | 17.8 | 2. | 14. | 28.3 | 0.89 | 0 to +16 | — 5 to +21 |
| 13 | 1,363 | 2.4 | 17.15 | 1.75 | 12.6 | 19.8 | 0.69 | +10 to +28 | 0 to +23 |
| 3 | 1,418 | 1.5 | 13.5 | 1.05 | 9.5 | 4.2 | 0.17 | +19 to +38 | + 6 to +30 |
| 1 | 1,435 | 1.5 | 13.05 | 1.05 | 9.05 | Dry | | +50 to +76 | +15 to +40 |
| 4+ | 1,464 | 1. | 11.1 | 0.7 | 7.6 | Dry | | — 2 to +15 | — 4 to +17 |
| Ave. 34 weeks | | | | | | | | | |
| | 1,317 | 2.39 | 17.2 | 1.85 | 13.1 | 23.25 | 0.76 | + 4 to +19 | — 2 to +21 |
| Ave. 39 weeks | | | | | | | | | |
| | 1,335 | 2.22 | 16.4 | 1.69 | 12.4 | 20.3 | 0.66 | + 5 to +19 | — 2 to +21 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,317 pounds.. | 0.922 | 10.44 | 0.922 | 10.44 | 0.783 | 8.53 |
| Milk, 23.25 pounds, 3¼%... | 1.116 | 6.95 | 1.372 | 7.04 | 1.418 | 6.79 |
| Total maintenance and milk (calculated) .......... | 2.038 | 17.39 | 2.294 | 17.48 | 2.201 | 15.32 |
| Total maintenance and milk (actual) .............. | 2.39 | 17.2 | 2.39 | 17.2 | 2.39 | 17.2 |
| ± ...................... | +17 | —1 | +4 | —2 | +9 | +12 |
| Armsby (conv. standard.. | 2.003 | 2.39 | +19% | 14.21 | 17.2 | +21% |
| Maintenance, 1,335 pounds.. | 0.934 | 10.59 | 0.934 | 10.59 | 0.794 | 8.65 |
| Milk, 20.3 pounds, 3¼%.. | 0.974 | 6.04 | 1.198 | 6.15 | 1.238 | 5.93 |
| Total maintenance and milk (calculated) .......... | 1.908 | 16.63 | 2.132 | 16.74 | 2.032 | 14.58 |
| Total maintenance and milk (actual) .............. | 2.22 | 16.4 | 2.22 | 16.4 | 2.22 | 16.4 |
| ± ...................... | +16 | —1 | +5 | —2 | +10 | +12 |
| Armsby (conv.) standard.. | 1.86 | 2.22 | +19% | 13.6 | 16.4 | +21% |

Altje had been in milk for about two and a half months when she was served. During this time she averaged 35 pounds of milk and 1.17 pounds of fat. During the succeeding eight and a half months she made an average of 23¼ pounds of milk and 0.76 pounds of fat. She ate somewhat more digestible protein than standard called for, the excess ranging from 1/25 to 1/5, while her total digestible nutrient intake ranged from 0 to 1/5 excess according to the standard.

VIII. 3. BONTJE, grade Holstein, 11 years old, was fed the low protein ration for 283 days from August 26, 1913 to June 5, 1914, from service to calving. Her feeding record follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| $9^2/_7$ | 10. | 36. | 5.4 | 5 | 10. | 30. | 3. |
| 1 | 10. | 30. | 5.2 | 2 | 10. | 29.9 | 2.4 |
| 1 | 8.7 | 23.6 | 4.2 | $6^1/_7$ | 9. | 29.3 | 2. |
| 16 | 10. | 30. | 4.3 | | | | |

Her nutrient intake, yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 9+ | 1,165 | 1.25 | 12.65 | 1.07 | 10.85 | 13.9 | 0.49 | —13 to —25 | — 8 to + 4 |
| 1 | 1,167 | 1.2 | 12.15 | 1.05 | 10.4 | 12.3 | 0.47 | —13 to —25 | — 9 to +11 |
| 1 | 1,146 | 1. | 10.05 | 0.85 | 8.75 | 8. | 0.31 | —13 to —25 | —15 to + 3 |
| 16 | 1,171 | 1.05 | 10.95 | 0.9 | 9.35 | 10.5 | 0.37 | —16 to —28 | —14 to + 7 |
| 5 | 1,232 | 1. | 10.7 | 0.8 | 8.7 | 4.9 | 0.21 | — 2 to —16 | — 7 to +13 |
| 2 | 1,284 | 0.95 | 10.4 | 0.75 | 8.1 | 1.6 | 0.07 | — 5 to +10 | — 3 to +18 |
| 6+ | 1,281 | 0.9 | 10.5 | 0.7 | 8.2 | Dry | | 0 to +18 | + 3 to +27 |
| Ave. 34 weeks | | | | | | | | | |
| | 1,184 | 1.09 | 11.25 | 0.92 | 9.55 | 10. | 0.36 | —12 to —23 | — 9 to +10 |
| Ave. 40 weeks | | | | | | | | | |
| | 1,199 | 1.06 | 11.15 | 0.89 | 9.35 | 8.55 | 0.31 | —10 to —20 | — 8 to +12 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,184 pounds.. | 0.830 | 9.39 | 0.83 | 9.39 | 0.705 | 7.67 |
| Milk, 10. pounds, 3½%.... | 0.490 | 3.13 | 0.61 | 3.19 | 0.62 | 3.02 |
| Total maintenance and milk (calculated) .......... | 1.32 | 12.52 | 1.44 | 12.58 | 1.325 | 10.69 |
| Total maintenance and milk (actual) .............. | 1.09 | 11.25 | 1.09 | 11.25 | 1.09 | 11.25 |
| ± ........................ | —17 | —10 | —24 | —11 | —18 | +5 |
| Armsby (conv.) standard.. | 1.245 | 1.09 | —12% | 10.24 | 11.25 | +10% |
| Maintenance, 1,199 pounds.. | 0.839 | 9.51 | 0.839 | 9.51 | 0.714 | 7.77 |
| Milk, 8.45 pounds, 3½%.... | 0.419 | 2.68 | 0.522 | 2.78 | 0.530 | 2.58 |
| Total maintenance and milk (calculated) .......... | 1.258 | 12.19 | 1.361 | 12.29 | 1.244 | 10.35 |
| Total maintenance and milk (actual) .............. | 1.06 | 11.15 | 1.06 | 11.15 | 1.06 | 11.15 |
| ± ........................ | —16 | —9 | —22 | —9 | —15 | +8 |
| Armsby (conv.) standard.. | 1.176 | 1.09 | —10% | 9.97 | 11.2 | +12% |

Bontje had been in milk for 16½ months prior to service, during which time she averaged 24 pounds of milk and 0.82 pounds of fat, which is a fairly good record in view of the fact that she was underfed. The cow then, during the last 34 weeks of her long lactation, averaged 10 pounds of milk and 0.36 pounds of fat and this on a continued restricted ration. She received from 1/10 to ¼ too little digestible protein and from 1/10 too little to 1/10 excess of total digestible nutrients. In view of her long continued low nutritional plane she certainly did well.

VIII. 4. BONTJE, grade Holstein, 12 years old, was fed for 280 days from September 15, 1914 to June 22, 1915, from service to calving. She was fed the low protein ration. Her food and nutrient intake, with milk and fat yields follow:

| Weeks | Hay | Silage | Grain | Crude protein | Total digestible nutrients | Milk | Fat |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| $3\,^2/_7$ | 8. | 20. | 7.8 | 1.35 | 11.75 | 17. | 0.52 |
| 5 | 8. | 25. | 7.7 | 1.3 | 11.7 | 15.4 | 0.49 |
| 3 | 8. | 25. | 8.8 | 1.35 | 11.75 | 16.5 | 0.56 |
| 3 | 7. | 20. | 9.2 | 1.35 | 11.25 | 16.8 | 0.53 |
| 18 | 7. | 16. | 9.2 | 1.35 | 11.4 | 10.6 | 0.36 |
| $7\,^5/_7$ | 7. | 16. | 9.2 | 1.45 | 10.95 | Dry | ... |
| Average 32 weeks | | | | 1.34 | 11.5 | 13.15 | 0.43 |
| Average 40 weeks | | | | 1.37 | 11.4 | 10.45 | 0.34 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,100* pounds. | 0.770 | 8.72 | 0.770 | 8.72 | 0.655 | 7.13 |
| Milk, 13.15 pounds, 3¼%.. | 0.631 | 3.93 | 0.776 | 3.98 | 0.802 | 3.85 |
| Total maintenance and milk (calculated) .......... | 1.401 | 12.65 | 1.546 | 12.7 | 1.457 | 10.98 |
| Total maintenance and milk (actual) ............. | 1.34 | 11.45 | 1.34 | 11.45 | 1.34 | 11.45 |
| ± ...................... | —4 | —9 | —13 | —10 | —8 | +4 |
| Armsby (conv.) standard.. | 1.346 | 1.34 | 0 | 10.34 | 11.45 | +11% |
| Maintenance, 1,110* pounds. | 0.777 | 8.80 | 0.777 | 8.80 | 0.660 | 7.19 |
| Milk, 10.45 pounds, 3¼%... | 0.502 | 3.11 | 0.617 | 3.17 | 0.637 | 3.05 |
| Total maintenance and milk (calculated) .......... | 1.279 | 11.91 | 1.394 | 11.97 | 1.297 | 10.24 |
| Total maintenance and milk (actual) ............. | 1.37 | 11.45 | 1.37 | 11.45 | 1.37 | 11.45 |
| ± ...................... | +7 | —4 | —2 | —4 | +6 | +12 |
| Armsby (conv.) standard.. | 1.208 | 1.37 | +13% | 9.74 | 11.45 | +18% |

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*Hypothetical.

Bontje's weight records were in the lost volumes (see pages 11-12) and, consequently, only a general statement can be made in this instance in connection with her nutrient intake and her milk and fat yields.

Bontje had been in milk for a little over three months at time of service and had made an average of 25 pounds of milk and 0.69 pounds of fat. She had been decidedly underfed during this time and, as a result, her subsequent average daily record for the last eight months of lactation was only 13.15 pounds of milk and 0.43 pounds of fat. Her digestible protein intake varied from a deficiency of 1/8 to an excess of 1/8, her total digestible nutrient intake from a deficiency of 1/10 to an excess of 1/6. She hardly had a fair chance to do her best.

VIII. 5. DURTJE, grade Holstein, nine years old; was fed the high protein ration for 282 days from service to calving, June 9, 1911 to March 16, 1912. Service took place 33 weeks subsequent to her previous calving and, consequently, the cow was dry during about three-fifths of the period now under consideration. Her feeding was of course greatly modified as is indicated in the subjoined statement.

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 5 | 12. | 40. | 9. | 13 | 12. | 40. | 3. |
| 8 | 12. | 40. | 6.1 | 3 | 12. | 30. | 3. |
| 3 | 12. | 40. | 3.2 | 8 | 10. | 30. | 3. |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual |  | Per 1,000 pounds live weight |  | Actual |  | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield |  |  |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 5 | 1,318 | 3.15 | 18.05 | 2.4 | 13.7 | 19.5 | 0.67 | +49 to +72 | + 8 to +33 |
| 8 | 1,344 | 2.3 | 16.25 | 1.7 | 12.05 | 10.6 | 0.37 | +45 to +68 | +16 to +42 |
| 3 | 1,358 | 1.6 | 13.1 | 1.2 | 9.65 | 5.5 | 0.21 | +23 to +43 | + 3 to +27 |
| 13 | 1,418 | 1.65 | 12.9 | 11.5 | 9.1 | Dry |  | +66 to +98 | +15 to +41 |
| 3 | 1,479 | 1.5 | 11.8 | 1. | 8. | Dry |  | +45 to +71 | + 1 to +23 |
| 8 | 1,472 | 1.45 | 10.75 | 1. | 7.3 | Dry |  | +41 to +66 | — 8 to +13 |
| Ave. 16 weeks | 1,341 | 2.45 | 16.2 | 1.83 | 12.1 | 12.4 | 0.43 | +45 to +67 | +11 to +36 |
| Ave. 40 weeks | 1,401 | 1.91 | 13.75 | 1.36 | 9.8 | 4.95 | 0.17 | +49 to +74 | + 8 to +33 |

|  | Haecker |  | Savage |  | Eckles (converted) |  |
|---|---|---|---|---|---|---|
|  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
|  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 1,341 pounds.. | 0.939 | 10.64 | 0.939 | 10.64 | 0.798 | 8.69 |
| Milk, 12.4 pounds, 3½%.... | 0.608 | 3.88 | 0.756 | 3.96 | 0.769 | 3.74 |
| Total maintenance and milk (calculated) .......... | 1.547 | 14.52 | 1.695 | 14.6 | 1.567 | 12.43 |
| Total maintenance and milk (actual) .............. | 2.45 | 16.2 | 2.45 | 16.2 | 2.45 | 16.2 |
| ± ........................ | +58 | +12 | +45 | +11. | +56 | +31 |
| Armsby (conv.) standard.. | 1.468 | 2.45 | +67% | 11.87 | 16.2 | +36% |
| Maintenance, 1,401 pounds.. | 0.981 | 11.11 | 0.981 | 11.11 | 0.834 | 9.05 |
| Milk, 4.95 pounds, 3½%... | 0.243 | 1.55 | 0.302 | 1.58 | 0.306 | 1.54 |
| Total maintenance and milk (calculated) .......... | 1.224 | 12.66 | 1.283 | 12.69 | 1.14 | 10.59 |
| Total maintenance and milk (actual) .............. | 1.91 | 13.75 | 1.91 | 13.75 | 1.91 | 13.75 |
| ± ........................ | +56 | +9 | +49 | +8 | +68 | +30 |
| Armsby (conv.) standard.. | 1.1 | 1.91 | +74% | 10.34 | 13.75 | +33% |

Durtje, during the eight months of her lactation prior to service, had given 38.1 pounds of milk and 1.08 pounds of fat. During the 16 weeks in which she closed her lactation, with which the present period is concerned, she averaged 12.4 pounds of milk and 0.43 pounds of fat. She then remained dry for 16 weeks. Being fed the high protein ration, she naturally received a great excess of this nutrient, as, indeed, was often the case when she was in full flush of milk, the excess ranging from ½ to ¾. She likewise was overfed in respect to her total digestible nutrient intake to the extent of from 1/12 to 3/7. She evidently had very much more to do with than was needed.

It is interesting to note that when Durtje calved, she dropped a large healthy calf but promptly lost half her udder and was discarded as useless. It is an open question whether or not her very liberal feeding during the 16 weeks that she was dry was not a factor in bringing about this mishap.

VIII. 6. Hazel K., grade Jersey, eight years old, was fed the low protein ration for 283 days, from March 8 to December 15, 1911, from service to calving. She was more than six months in lactation at the time of service. She was dry for about two-fifths of the period now under review and her feeding was modified accordingly, as is shown in the following statement:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| 6 | 12. | 30. | 6. | 2 | 10. | 30. | 5. |
| 12 | 10. | 30. | 6. | 6 | 10. | 30. | 2. |
| 6 | 10. | 30. | 5.3 | 8 | 10. | 20. | 2. |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual<br>Digestible protein | Actual<br>Total digestible nutrients | Per 1,000 pounds live weight<br>Digestible protein | Per 1,000 pounds live weight<br>Total digestible nutrients | Actual<br>Milk yield | Actual<br>Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 6 | 968 | 1.65 | 14.6 | 1.7 | 15.1 | 14.1 | 0.76 | — 5 to + 6 | + 8 to +26 |
| 12 | 970 | 1.5 | 13.45 | 1.55 | 13.9 | 12.5 | 0.65 | — 7 to + 6 | + 4 to +26 |
| 6 | 1,003 | 1.25 | 13.3 | 1.25 | 13.3 | 6.9 | 0.35 | + 4 to + 19 | +24 to +51 |
| 2 | 1,045 | 1.25 | 13.3 | 1.2 | 12.75 | Dry | | +71 to +101 | +61 to +97 |
| 6 | 1,011 | 1. | 10. | 1. | 9.9 | Dry | | +41 to + 67 | +25 to +53 |
| 8 | 1,011 | 0.85 | 9. | 0.85 | 8.9 | Dry | | +21 to + 43 | +12 to +37 |
| Ave. 24 weeks | 978 | 1.48 | 13.7 | 1.51 | 14. | 11.5 | 0.60 | — 4 to + 9 | + 9 to +32 |
| Ave. 40 weeks | 993 | 1.25 | 12.2 | 1.26 | 12.3 | 6.9 | 0.36 | + 3 to + 12 | + 4 to +38 |

| | Haecker<br>Digestible protein | Haecker<br>Total digestible nutrients | Savage<br>Digestible protein | Savage<br>Total digestible nutrients | Eckles (converted)<br>Digestible protein | Eckles (converted)<br>Total digesti nutrie |
|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 978 pounds... | 0.685 | 7.76 | 0.685 | 7.76 | 0.582 | 6.34 |
| Milk, 11.5 pounds, 5¼%.... | 0.713 | 4.73 | 0.863 | 4.81 | 0.880 | 4.73 |
| Total maintenance and milk (calculated) .......... | 1.398 | 12.49 | 1.548 | 12.57 | 1.462 | 11.07 |
| Total maintenance and milk (actual) .............. | 1.48 | 13.7 | 1.48 | 13.7 | 1.48 | 13.7 |
| ± ...................... | +6 | +10 | —4 | +9 | +1 | +24 |
| Armsby (conv.) standard.. | 1.358 | 1.48 | + 9% | 10.4 | 13.7 | +32% |
| Maintenance, 993 pounds... | 0.695 | 7.87 | 0.695 | 7.87 | 0.591 | 6.43 |
| Milk, 6.9 pounds, 5¼%.... | 0.428 | 2.84 | 0.518 | 2.88 | 0.528 | 2.84 |
| Total maintenance and milk (calculated) .......... | 1.123 | 10.71 | 1.213 | 10.75 | 1.119 | 9.27 |
| Total maintenance and milk (actual) .............. | 1.28 | 12.2 | 1.28 | 12.2 | 1.28 | 11.2 |
| ± ...................... | +14 | +14 | +6 | +14 | +14 | +32 |
| Armsby (conv.) standard.. | 1.057 | 1.28 | +21% | 8.87 | 12.2 | +38% |

Hazel K. was underfed during the first six months of lactation and gave an average of 19.6 pounds of milk and 1.06 pounds of fat. During the period of her gestation, however, she received a sufficiency of digestible protein and more than a sufficiency of total digestible nutrients, her digestible protein intake varying from +1/16 to +1/5 and her total digestible nutrient intake from +1/7 to +3/8. During the six months she was in milk, she held up her flow fairly well, averaging 11.5 pounds of milk and 0.6 pounds of fat. She seems to have done reasonably well as, indeed, it would seem she should do.

VIII. 7. HAZEL K., grade Jersey, nine years old, was fed the low protein ration for 273 days, from February 2 to November 9, 1912, from service to calving. She was served less than two months after she calved. Her feeding record follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| 25 | 10. | 30. | 8.9 | 6 | 10. | 30. | 1.7 |
| 5 | 10. | 30. | 6. | 3 | 10. | 30. | 2.4 |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual: Digestible protein | Actual: Total digestible nutrients | Per 1,000 pounds live weight: Digestible protein | Per 1,000 pounds live weight: Total digestible nutrients | Actual: Milk yield | Actual: Fat yield | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 25 | 889 | 1.65 | 14.4 | 1.85 | 16.2 | 18.6 | 0.95 | + 6 to —19 | — 3 to +19 |
| 5 | 948 | 1.35 | 13. | 1.4 | 13.7 | 6.7 | 0.36 | +14 to +32 | +25 to +51 |
| 6 | 1,004 | 1. | 10.3 | 1. | 10.25 | Dry | | +43 to +68 | +29 to +58 |
| 3 | 1,016 | 1. | 10.2 | 1. | 10. | Dry | | +41 to +66 | +27 to +55 |
| Ave. 30 weeks | 899 | 1.6 | 14.2 | 1.78 | 15.8 | 16.7 | 0.85 | — 2 to —15 | + 1 to +24 |
| Ave. 39 weeks | 925 | 1.46 | 13.3 | 1.60 | 14.5 | 12.8 | 0.65 | + 5 to —10 | + 5 to +29 |

| | Haecker: Digestible protein | Haecker: Total digestible nutrients | Savage: Digestible protein | Savage: Total digestible nutrients | Eckles (converted): Digestible protein | Eckles (converted): Total digestible nutrients |
|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 899 pounds... | 0.629 | 7.13 | 0.629 | 7.13 | 0.535 | 5.83 |
| Milk, 16.7 pounds, 5%...... | 1.002 | 6.65 | 1.219 | 6.76 | 1.236 | 6.50 |
| Total maintenance and milk (calculated) .......... | 1.631 | 13.78 | 1.848 | 13.89 | 1.771 | 12.33 |
| Total maintenance and milk (actual) .............. | 1.6 | 14.2 | 1.6 | 14.2 | 1.6 | 14.2 |
| ± ...................... | —2 | +3 | —13 | +2 | —10 | +15 |
| Armsby (conv.) standard.. | 1.637 | 1.6 | — 2% | 11.51 | 14.2 | +24% |
| Maintenance, 927 pounds... | 0.643 | 7.34 | 0.648 | 7.34 | 0.541 | 6.00 |
| Milk, 12.8 pounds, 5%..... | 0.768 | 5.09 | 0.934 | 5.18 | 0.947 | 4.98 |
| Total maintenance and milk (calculated) .......... | 1.416 | 12.43 | 1.582 | 12.52 | 1.488 | 10.98 |
| Total maintenance and milk (actual) ............. | 1.46 | 13.3 | 1.46 | 13.3 | 1.46 | 13.3 |
| ± ...................... | +3 | +7 | —8 | +6 | —2 | +21 |
| Armsby (conv.) standard.. | 1.386 | 1.46 | + 5% | 10.34 | 13.3 | +29% |

Hazel K. was underfed during the first two months of her lactation, yet made 24.3 pounds of milk and 1.2 pounds of fat. She dried off somewhat quickly, however, and averaged during the period under consideration 16.7 pounds of milk and 0.85 pounds of fat. Her underfeeding continued in respect to digestible protein but she seemed to receive enough total digestible nutrients, the figures being as follows: digestible protein, $+\frac{1}{20}$ to $-\frac{1}{7}$; total digestible nutrients, 0 to $+\frac{1}{4}$. As is elsewhere pointed out, Hazel K. gave only 4,700 pounds of milk and 177 pounds of fat during her entire lactation. In view of her somewhat restricted ration, this record is not perhaps to be wondered at.

VIII. 8. JANE, grade Jersey, eight years old, was fed the high protein ration for 282 days from December 5, 1910 to September 13 1911, from service to calving. She was served when about six months in lactation. Her somewhat varied feeding record follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. | Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|---|---|---|---|
| $9^{4}/_{7}$ | 14. | 36. | 8. | 4 | 10. | 30. | 6. |
| 4 | 13. | 36. | 7. | 1 | 10. | 30. | 2.3 |
| 6 | 12. | 36. | 6. | 2 | 10. | 30. | .. |
| 8 | 10. | 36. | 6. | $5^{5}/_{7}$ | 10. | 30. | .. |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual |  | Per 1,000 pounds live weight |  | Actual |  | Digestible protein ± of standards | Total digestible nutrients ± of standards |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield |  |  |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % % | % % |
| 9+ | 884 | 3. | 17.8 | 3.4 | 20.15 | 18.4 | 1.11 | +42 to + 62 | +16 to +31 |
| 4 | 894 | 2.75 | 16.35 | 3.1 | 18.3 | 15.1 | 0.93 | +46 to + 66 | +14 to +37 |
| 6 | 910 | 2.45 | 15.4 | 2.7 | 16.9 | 14. | 0.91 | +34 to + 53 | +10 to +31 |
| 8 | 938 | 2.25 | 14.35 | 2.4 | 15.3 | 11.1 | 0.71 | +47 to + 64 | +12 to +34 |
| 4 | 962 | 2.2 | 13.6 | 2.3 | 14.15 | 6.8 | 0.41 | +80 to +106 | +27 to +53 |
| 1 | 983 | 1.3 | 10.95 | 1.35 | 11.15 | 6.5 | 0.32 | +10 to + 29 | + 3 to +28 |
| 2 | 982 | 0.7 | 9.6 | 0.7 | 9.8 | 2.75 | 0.14 | — 9 to — 24 | + 5 to +31 |
| 5+ | 1,006 | 0.7 | 9.6 | 0.7 | 9.55 | Dry |  | — 1 to +17 | +20 to +47 |
| Ave. 34 weeks | 920 | 2.42 | 15.2 | 2.66 | 16.4 | 12.9 | 0.80 | +42 to + 60 | +14 to +36 |
| Ave. 40 weeks | 931 | 2.16 | 14.4 | 2.36 | 15.6 | 10.95 | 0.68 | +43 to + 57 | +14 to +38 |

|  | Haecker |  | Savage |  | Eckles (converted) |  |
|---|---|---|---|---|---|---|
|  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
|  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 920 pounds... | 0.644 | 7.30 | 0.644 | 7.30 | 0.547 | 5.96 |
| Milk, 12.9 pounds, 6¼%... | 0.897 | 6.01 | 1.071 | 6.08 | 1.109 | 6.62 |
| Total maintenance and milk (calculated) .......... | 1.541 | 13.31 | 1.715 | 13.38 | 1.656 | 12.58 |
| Total maintenance and milk (actual) ............. | 2.42 | 15.2 | 2.42 | 15.2 | 2.42 | 15.2 |
| ± ...................... | +57 | +14 | +41 | +13 | +46 | +20 |
| Armsby (conv.) standard.. | 1.508 | 2.42 | +60% | 11.16 | 15.2 | +36% |
| Maintenance, 933 pounds... | 0.653 | 7.40 | 0.653 | 7.40 | 0.555 | 6.05 |
| Milk, 10.95 pounds, 6¼%... | 0.761 | 5.10 | 0.909 | 5.10 | 0.943 | 5.62 |
| Total maintenance and milk (calculated) .......... | 1.414 | 12.50 | 1.562 | 12.50 | 1.498 | 11.67 |
| Total maintenance and milk (actual) .............. | 2.16 | 14.4 | 2.16 | 14.4 | 2.16 | 14.4 |
| ± ...................... | +53 | +15 | +38 | +15 | +44 | +23 |
| Armsby (conv.) standard.. | 1.371 | 2.16 | +57% | 10.46 | 14.4 | +38% |

During six months' lactation prior to service, Jane averaged 25 pounds of milk and 1.21 pounds of fat. She maintained her milk flow until nearly calving and during the 34 weeks of the last half of her lactation she averaged 12.9 pounds of milk and 0.8 pounds of fat. However, she ate from 3/8 to 3/5 more digestible protein and from 1/8 to 3/8 more total digestible nutrients than standards indicated she needed. Receiving plenty she responded.

VIII. 9. SABRA, grade Jersey, eight years old, was fed the medium protein ration for 276 days, from October 11, 1910 to July 14, 1911, from service to calving. Her feeding record follows:

| Weeks | Hay | Silage | Grain | Weeks | Hay | Silage | Grain |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. |
| $17^{3}/_{7}$ | 14. | 36. | 8. | 2 | 10. | 36. | 6. |
| 2 | 14. | 36. | 7. | 1 | 10. | 36. | .. |
| 2 | 12. | 36. | 7. | 5 | 10. | 36. | .. |
| 6 | 12. | 36. | 6. | 4 | 10. | 30. | .. |

Her nutrient intake, fat yields and comparison data follow:

| Duration | Live weight | Actual | | Per 1,000 pounds live weight | | Actual | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield | Digestible protein ± of standards | | Total digestible nutrients ± of standards | |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| 17+ | 902 | 2.4 | 17.5 | 2.65 | 19.4 | 18.5 | 1.14 | +11 to | +25 | +10 to | +32 |
| 2 | 920 | 2.35 | 17.15 | 2.55 | 18.65 | 15.6 | 0.98 | +21 to | +38 | +17 to | +40 |
| 2 | 943 | 2.3 | 16.1 | 2.45 | 17.1 | 12.5 | 0.81 | +34 to | +52 | +19 to | +43 |
| 6 | 972 | 2.1 | 15.5 | 2.15 | 15.95 | 8.6 | 0.60 | +45 to | +62 | +28 to | +54 |
| 2 | 990 | 1.95 | 14.25 | 1.95 | 14.4 | 4.9 | 0.35 | +73 to | +98 | +38 to | +68 |
| 1 | 986 | 1.05 | 10.4 | 1.05 | 10.55 | 1.4 | 0.10 | +29 to | +50 | +22 to | +49 |
| 5 | 988 | 1. | 10.3 | 1. | 10.45 | Dry | | +45 to | +70 | +32 to | +61 |
| 4 | 990 | 0.8 | 9.55 | 0.8 | 9.65 | Dry | | +16 to | +36 | +22 to | +49 |
| Ave. 30 weeks | | | | | | | | | | | |
| | 929 | 2.26 | 16.55 | 2.43 | 17.8 | 14.5 | 0.91 | +22 to | +38 | +16 to | +39 |
| Ave. 39 weeks | | | | | | | | | | | |
| | 943 | 1.95 | 15. | 2.08 | 16. | 11.2 | 0.70 | +21 to | +40 | +17 to | +41 |

| | Haecker | | Savage | | Eckles (converted) | |
|---|---|---|---|---|---|---|
| | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs |
| Maintenance, 929 pounds... | 0.650 | 7.37 | 0.650 | 7.37 | 0.553 | 6.02 |
| Milk, 14.5 pounds, 6¼%.... | 1.008 | 6.76 | 1.204 | 6.83 | 1.247 | 7.44 |
| Total maintenance and milk (calculated) .......... | 1.658 | 14.13 | 1.854 | 14.2 | 1.8 | 13.46 |
| Total maintenance and milk (actual) .............. | 2.26 | 16.55 | 2.26 | 16.55 | 2.26 | 16.55 |
| ± ...................... | +36 | +17 | +22 | +17 | +26 | +23 |
| Armsby (conv.) standard.. | 1.633 | 2.26 | +38% | 11.86 | 16.55 | +39% |
| Maintenance, 943 pounds... | 0.660 | 7.48 | 0.66 | 7.48 | 0.561 | 6.11 |
| Milk, 11.2 pounds, 6¼%.... | 0.780 | 5.22 | 0.93 | 5.28 | 0.63 | 5.75 |
| Total maintenance and milk (calculated) .......... | 1.44 | 12.7 | 1.59 | 12.76 | 1.524 | 11.86 |
| Total maintenance and milk (actual) .............. | 1.95 | 15. | 1.95 | 15. | 1.95 | 15. |
| ± ...................... | +35 | +18 | +23 | +17 | +28 | +26 |
| Armsby (conv.) standard.. | 1.395 | 1.95 | +40% | 10.62 | 15. | +41% |

Sabra had aborted five months prior to her service and during these five months had given 23.5 pounds of milk and 1.24 pounds of fat. She continued for 30 weeks more in milk, giving 14.5 and 0.91 pounds respectively of milk and fat—a reasonably good record under the circumstances. However, fed somewhat liberally as she was with the medium protein ration, she ate more food than standards indicated, the excesses being: digestible protein ⅕ to ⅖; total digestible nutrients, ⅙ to ⅖. From the standpoint of the maintenance of good health in the case of a cow thus unfortunate, a bountiful ration was doubtless indicated.

VIII. 10. SABRA, grade Jersey, nine years old, was fed the medium protein ration while in milk and dry for 276 days, from December 26, 1911 to September 29, 1912, from service to calving. She was served about six months after calving, remaining in milk after service about five months, being dry about four months. Her feeding record follows:

| Weeks | Hay lbs. | Silage lbs. | Grain lbs. |
|---|---|---|---|
| $13^3/_7$ | 10. | 30. | 8.6 |
| 9 | 10. | 30. | 7. |
| 1 | 10. | 30. | 5.2 |
| 8 | 10. | 30. | 5.2 |
| 1 | 10. | 30. | 3. |
| 5 | 10. | 30. | .. |
| 2 | 10. | 30. | .. |

Her nutrient intake, milk and fat yields and comparison data follow:

| Duration | Live weight | Actual |  | Per 1,000 pounds live weight |  | Actual |  | ± Digestible protein of standards |  | ± Total digestible nutrients of standards |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Milk yield | Fat yield |  |  |  |  |
| Weeks | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | % | % | % | % |
| 13+ | 870 | 2.1 | 14.45 | 2.4 | 16.6 | 15.9 | 0.96 | + 11 to | + 25 | + 3 to | +22 |
| 9 | 902 | 1.9 | 13.4 | 2.1 | 14.85 | 11.5 | 0.70 | + 22 to | + 38 | + 8 to | +30 |
| 1 | 930 | 1.55 | 12.15 | 1.65 | 13.05 | 2.8 | 0.17 | + 77 to | +105 | +40 to | +70 |
| 8 | 971 | 1.6 | 12.05 | 1.65 | 12.4 | Dry |  | +147 to | +178 | +56 to | +92 |
| 1 | 1,018 | 1.25 | 10.75 | 1.25 | 10.55 | Dry |  | + 75 to | +106 | +34 to | +63 |
| 5 | 1,024 | 0.8 | 9.2 | 0.8 | 9. | Dry |  | + 12 to | + 32 | +13 to | +39 |
| 2 | 1,026 | 1.05 | 10.2 | 1. | 9.95 | Dry |  | + 46 to | + 72 | +25 to | +54 |
| Ave. 23 weeks | 885 | 2. | 13.95 | 2.25 | 15.75 | 13.6 | 0.83 | + 15 to | + 32 | + 5 to | +26 |
| Ave. 39 weeks | 931 | 1.69 | 12.7 | 1.85 | 13.75 | 8. | 0.49 | + 29 to | + 49 | +15 to | +39 |

|  | Haecker |  | Savage |  | Eckles (converted) |  |
|---|---|---|---|---|---|---|
|  | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients | Digestible protein | Total digestible nutrients |
|  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Maintenance, 885 pounds... | 0.620 | 7.02 | 0.62 | 7.02 | 0.527 | 5.73 |
| Milk, 13.6 pounds, 6%..... | 0.911 | 6.13 | 1.102 | 6.22 | 1.129 | 6.61 |
| Total maintenance and milk (calculated) .......... | 1.531 | 13.15 | 1.722 | 13.25 | 1.656 | 12.34 |
| Total maintenance and milk (actual) ............. | 2. | 13.95 | 2. | 13.95 | 2. | 13.95 |
| ± ...................... | +31 | +6 | +16 | +5 | +21 | +13 |
| Armsby (conv.) standard.. | 1.52 | 2. | +32% | 11.03 | 13.95 | +26% |
| Maintenance, 931 pounds... | 0.652 | 7.38 | 0.652 | 7.38 | 0.554 | 6.03 |
| Milk, 8 pounds, 6%......... | 0.536 | 3.61 | 0.648 | 3.66 | 0.664 | 3.89 |
| Total maintenance and milk (calculated) .......... | 1.188 | 10.99 | 1.3 | 11.04 | 1.218 | 9.92 |
| Total maintenance and milk (actual) ............. | 1.69 | 12.7 | 1.69 | 12.7 | 1.69 | 12.7 |
| ± ...................... | +42 | +15 | +30 | +15 | +39 | +28 |
| Armsby (conv.) standard.. | 1.138 | 1.69 | +49% | 9.15 | 12.7 | +39% |

Sabra had made 20.1 pounds of milk and 1.09 pounds of fat during the five and a half months prior to service, and made 13.6 pounds and 0.83 pounds respectively during the last five and a half months of her lactation. Prior to service she received a barely standard ration, but after service a super-standard ration, the excesses being: digestible protein, $\frac{1}{6}$ to $\frac{1}{2}$; total digestible nutrients, $\frac{1}{20}$ to $\frac{2}{3}$. It would seem as if with the food she had, she might have maintained her milk flow longer. She was fed much more than she needed while she was dry.

The low protein fed cows ate 1.29 and 12 pounds, the medium protein fed cows 2.04 and 15.3 and the high protein fed cows 2.04 and 14.1 pounds, respectively, of digestible protein and digestible dry matter. They made on the average 9.7, 14.5 and 8 pounds of milk.

COMPARISON WITH STANDARDS

| | Entire lot (10 records) | | Low protein (4 records) | | Medium protein (4 records) | | High protein (2 records) | |
|---|---|---|---|---|---|---|---|---|
| Average live weights, lbs....... | 1,118 | | 1,060 | | 1,152 | | 1,167 | |
| Average digestible protein and total digestible nutrients intakes, lbs. .................. | 1.74 | 13.75 | 1.29 | 12. | 2.04 | 15.3 | 2.04 | 14.1 |
| Average digestible protein and total digestible nutrients intakes (Haecker), lbs......... | 1.42 | 13. | 1.27 | 11.8 | 1.61 | 14.35 | 1.32 | 12.6 |
| Average digestible protein and total digestible nutrients intakes (Savage), lbs. .......... | 1.56 | 13.05 | 1.39 | 11.9 | 1.79 | 14.45 | 1.42 | 12.6 |
| Average digestible protein and total digestible nutrients intakes (Eckles, converted), lbs. | 1.47 | 11.5 | 1.29 | 10.2 | 1.69 | 12.75 | 1.37 | 11.15 |
| Average digestible protein and total digestible nutrients intakes (Armsby, converted), lbs. | 1.36 | 10.8 | 1.21 | 9.75 | 1.56 | 11.85 | 1.24 | 10.4 |
| ± (Haecker) ................ | +22 | + 6. | +2 | + 2 | +28 | + 8 | +55 | +12 |
| ± (Savage) .................. | +12 | + 5 | —7 | + 2 | +16 | + 7 | +44 | +12 |
| ± (Eckles, converted)......... | +18 | +20 | +1 | +18 | +21 | +20 | +50 | +25 |
| ± (Armsby, converted) ...... | +28 | +28 | +7 | +24 | +33 | +31 | +65 | +36 |

The cows were overfed as a rule. The low protein fed cows ate barely enough digestible protein, but standard (H., S.) or ⅕ to ¼ super-standard (E., A.) amounts of digestible dry matter. The medium and high protein fed cows were heavily overfed by any and all standards, especially in respect to digestible protein.

Treating these records now in the same manner as similar records were handled in sections III and IV we have the following statement:

| | Average live weights in successive five-week periods following service | | | | | | | | Live weights after calving | Approximate weights | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Calf | Placenta, etc. |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VIII. 1. Altje | 1,356 | 1,367 | 1,373 | 1,389 | 1,397 | 1,418 | 1,430 | 1,433 | 1,250 | 125 | 55 |
| VIII. 2. Altje | 1,258 | 1,253 | 1,268 | 1,298 | 1,340 | 1,380 | 1,410 | 1,449 | 1,309 | 100 | 40 |
| VIII. 3. Bontje | 1,159 | 1,166 | 1,156 | 1,167 | 1,173 | 1,202 | 1,258 | 1,282 | 1,109 | 120 | 50 |
| VIII. 4. Bontje | Weight data missing (see pages 11-12). | | | | | | | | | | |
| VIII. 5. Durtje | 1,318 | 1,334 | 1,362 | 1,368 | 1,423 | 1,463 | 1,471 | 1,474 | 1,310 | 115 | 50 |
| VIII. 6. Hazel K. | 966 | 977 | 969 | 978 | 1,014 | 1,045 | 989 | 1,008 | 899 | 75 | 25 |
| VIII. 7. Hazel K. | 882 | 880 | 886 | 887 | 910 | 948 | 1,001 | 1,025 | 890 | 100 | 35 |
| VIII. 8. Jane | 877 | 887 | 896 | 918 | 936 | 948 | 977 | 1,006 | 892 | 85 | 30 |
| VIII. 9. Sabra | 885 | 908 | 910 | 913 | 958 | 984 | 988 | 989 | 824 | 115 | 50 |
| VIII. 10. Sabra | 873 | 873 | 868 | 898 | 926 | 964 | 1,009 | 1,028 | 920 | 80 | 30 |

These cows were fed better than those listed in section III. Five of the six listed in section III ate per 1,000 pounds live weight from 0.6 to 1 pound of digestible protein, averaging 0.75 pound; and from 4.9 to 6.1 pounds total digestible nutrients, averaging 5.5 pounds. These 10 cows listed in section VIII ate per 1,000 pounds live weight during their gestation periods 0.9 to 2.35 pounds digestible protein, averaging 1.6 pounds; and from 9.35 to 16 pounds total digestible nutrients, averaging 12.75 pounds. Hence it is, doubtless, that the shrinkages in live weight made by the cows listed in section III when calving ranged from 56 to 123 pounds, averaging 97 pounds; and in section VIII from 101 to 182 pounds, averaging 128 pounds. One cow listed in section III fed 2 pounds digestible protein and 12.3 pounds total digestible nutrients shrank in weight at calving 170 pounds. Of course this lot of 10 cows were in milk during part of the gestation period, whereas those listed in section III were not; but, notwithstanding, they had more to do with in building up the structures of their unborn calves.

Using the data in the above table and in the several tables, VIII 1 to 10, inclusive, and adopting the same assumptions as in section III as to the analyses of new-born calf and placenta, and the proportion of the latter to the ejecta, we have the following computations based upon the total actual nutrient intake for the entire gestation period expressed as pounds, and the calculated usage according to the different standards for maintenance and milk making.

| | Haecker (et al.) | | | Savage | | | Eckles (converted) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Digestible protein | Digestible carbohydrates and fat | nutrients Total digestible |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VIII. 1. Altje (grade Holstein); 278 days; medium protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 637 | 4,103 | 4,740 | 637 | 4,103 | 4,740 | 637 | 4,103 | 4,740 |
| Used milk and maintenance (calculated) .......... | 533 | 4,221 | 4,754 | 592 | 4,190 | 4,782 | 553 | 3,553 | 4,106 |
| Remaining for fœtal construction ............. | +104 | —118 | —14 | +45 | —87 | —42 | +84 | +550 | +634 |
| 155 pounds ejecta .......... | 31 | 14 | 45 | 31 | 14 | 45 | 31 | 14 | 45 |
| ± pounds ................ | +73 | —132 | —59 | +14 | —101 | —87 | +53 | +536 | +589 |
| VIII. 2. Altje (grade Holstein); 277 days; medium protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 615 | 3,928 | 4,543 | 615 | 3,928 | 4,543 | 615 | 3,928 | 4,543 |
| Used milk and maintenance (calculated) .......... | 529 | 4,078 | 4,607 | 591 | 4,046 | 4,637 | 563 | 3,476 | 4,039 |
| Remaining for fœtal construction ............. | +86 | —150 | —64 | +24 | —118 | —94 | +52 | +452 | +504 |
| 120 pounds ejecta .......... | 24 | 11 | 35 | 24 | 11 | 35 | 24 | 11 | 35 |
| ± pounds ................ | +72 | —161 | —99 | 0 | —129 | —129 | +28 | +441 | +469 |
| VIII. 3. Bontje (grade Holstein); 283 days; low protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 300 | 2,855 | 3,155 | 300 | 2,855 | 3,155 | 300 | 2,855 | 3,155 |
| Used milk and maintenance (calculated) .......... | 356 | 3,094 | 3,450 | 385 | 3,093 | 3,478 | 352 | 2,577 | 2,929 |
| Remaining for fœtal construction ............. | —56 | —239 | —295 | —85 | —238 | —323 | —52 | +278 | +226 |
| 145 pounds ejecta .......... | 29 | 13 | 42 | 29 | 13 | 42 | 29 | 13 | 42 |
| ± pounds ................. | —85 | —252 | —337 | —114 | —251 | —365 | —81 | +265 | +184 |
| VIII. 4. Bontje (grade Holstein); 280 days; low protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 350 | 2,548 | 2,898 | 350 | 2,548 | 2,898 | 350 | 2,548 | 2,898 |
| Used milk and maintenance (calculated) .......... | 358 | 2,977 | 3,335 | 390 | 2,962 | 3,352 | 363 | 2,504 | 2,867 |
| Remaining for fœtal construction ............ | —8 | —429 | —437 | —40 | —414 | —454 | —13 | +42 | +31 |
| 145 pounds ejecta .......... | 29 | 13 | 42 | 29 | 13 | 42 | 29 | 13 | 42 |
| ± pounds ................. | —37 | —442 | —479 | —69 | —427 | —496 | —42 | +29 | —11 |
| VIII. 5. Durtje (grade Holstein); 282 days; high protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 539 | 3,338 | 3,877 | 539 | 3,338 | 3,877 | 539 | 3,338 | 3,877 |
| Used milk and maintenance (calculated) .......... | 345 | 3,223 | 3,568 | 361 | 3,217 | 3,578 | 321 | 2,662 | 2,983 |
| Remaining for fœtal construction ............. | +194 | +115 | +309 | +178 | +121 | +299 | +218 | +676 | +894 |
| 140 pounds ejecta .......... | 28 | 13 | 41 | 28 | 13 | 41 | 28 | 13 | 41 |
| ± pounds ................. | +166 | +102 | +268 | +150 | +108 | +258 | +190 | +663 | +853 |

| | Haecker (et al.) | | | Savage | | | Eckles (converted) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients | Digestible protein | Digestible carbohydrates and fat | Total digestible nutrients |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VIII. 6. Hazel K. (grade Jersey); 283 days; low protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 362 | 3,091 | 3,453 | 362 | 3,091 | 3,453 | 362 | 3,091 | 3,453 |
| Used milk and maintenance (calculated) .......... | 317 | 2,714 | 3,031 | 343 | 2,699 | 3,042 | 316 | 2,307 | 2,623 |
| Remaining for fœtal construction ............. | +45 | +377 | +422 | +19 | +392 | +411 | +46 | +784 | +830 |
| 85 pounds ejecta .......... | 17 | 8 | 25 | 17 | 8 | 25 | 17 | 8 | 25 |
| ± pounds ............... | +28 | +369 | +397 | +2 | +384 | +386 | +29 | +776 | +805 |
| VIII. 7. Hazel K. (grade Jersey); 273 days; low protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 399 | 3,232 | 3,631 | 399 | 3,232 | 3,631 | 399 | 3,232 | 3,631 |
| Used milk and maintenance (calculated) .......... | 387 | 3,006 | 3,393 | 432 | 2,985 | 3,417 | 406 | 2,592 | 2,998 |
| Remaining for fœtal construction .............. | +12 | +226 | +238 | —33 | +247 | +214 | —7 | +640 | +633 |
| 720 pounds ejecta .......... | 24 | 11 | 35 | 24 | 11 | 35 | 24 | 11 | 35 |
| ± pounds ............... | —12 | +215 | +203 | —57 | +236 | +179 | —31 | +629 | +598 |
| VIII. 8. Jane (grade Jersey); 282 days; high protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 609 | 3,452 | 4,061 | 609 | 3,452 | 4,061 | 609 | 3,452 | 4,061 |
| Used milk and maintenance (calculated) .......... | 399 | 3,126 | 3,525 | 440 | 3,085 | 3,525 | 423 | 2,867 | 3,290 |
| Remaining for fœtal construction .............. | +210 | +326 | +536 | +169 | +367 | +536 | +186 | +585 | +771 |
| 100 pounds ejecta .......... | 20 | 9 | 29 | 20 | 9 | 29 | 20 | 9 | 29 |
| ± pounds ............... | +190 | +317 | +507 | +149 | +358 | +507 | +166 | +576 | +742 |
| VIII. 9. Sabra (grade Jersey); 276 days; medium protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 538 | 3,602 | 4,140 | 538 | 3,602 | 4,140 | 538 | 3,602 | 4,140 |
| Used milk and maintenance (calculated) .......... | 397 | 3,108 | 3,505 | 439 | 3,083 | 3,522 | 420 | 2,853 | 3,273 |
| Remaining for fœtal construction ............. | +141 | +494 | +635 | +99 | +519 | +618 | +118 | +749 | +867 |
| 140 pounds ejecta .......... | 28 | 13 | 41 | 28 | 13 | 41 | 28 | 13 | 41 |
| ± pounds ............... | +113 | +481 | +594 | +71 | +506 | +577 | +90 | +736 | +826 |
| VIII. 10. Sabra (grade Jersey); 276 days; medium protein ration | | | | | | | | | |
| Nutrient intake (actual)... | 466 | 3,039 | 3,505 | 466 | 3,039 | 3,505 | 466 | 3,039 | 3,505 |
| Used milk and maintenance (calculated) .......... | 328 | 2,705 | 3,033 | 359 | 2,688 | 3,047 | 336 | 2,402 | 2,738 |
| Remaining for fœtal construction ............. | +138 | +334 | +472 | +107 | +351 | +458 | +130 | +637 | +767 |
| 95 pounds ............... | 19 | 9 | 28 | 19 | 9 | 28 | 19 | 9 | 28 |
| ± pounds ............... | +119 | +325 | +444 | +88 | +342 | +430 | +111 | +628 | +739 |

The Armsby comparison ± data are not included in the table in order to preserve perpendicularity, as heretofore explained. They are, with a single exception, on the plus side of the equation from record 1 to record 10 as follows: 121, 719, 840; 100, 676, 776; —33, 366, 333; 8, 163, 171; 229, 732, 961; 63, 880, 943; 21, 792, 813; 223, 891, 1114; 153, 1056, 1209; 153, 827, 980.

Five records are consistently plus, namely, Durtje's (high protein), Hazel K.'s first (low protein), Jane's (high protein) and Sabra's two (medium protein). These cows ate enough and more than enough to make milk, to construct the fœtus and to maintain their own bodies.

Three records indicate an insufficient digestible protein intake, namely, Bontje's two (low protein) and Hazel K.'s second (low protein). Indeed these cows appeared to eat barely enough, and generally too little, of this nutrient to make milk to maintain themselves and naturally they had little or nothing wherewith to build up a fœtus—if we are to judge by standards; and yet their calves were vigorous, healthy and full sized. Bontje had no carbohydrates or fat left for fœtus construction, according to the Haecker et al. and Savage statements as to maintenance and milk needs, indeed not enough to supply these latter calls, but she had plenty according to the Eckles and Armsby (converted) standards. Hazel K. was able to supply plenty of total digestible nutrients for fœtal construction as indicated by any of the standards.

In two cases (Altje: medium protein) a sufficiency of digestible protein but an insufficiency of carbohydrates and fat were fed as judged by two and enough of both according to two standards.

Most of these cows were getting along in years and did not remain long after the trials discussed in this section were closed. Their post-parturition histories were uneventful and normal. Durtje, well fed with plenty to do with, lost two quarters of her udder at calving; but so did Bontje, who was perhaps underfed.

## IX. MAINTENANCE AND LACTATION: DATA FROM PROTEIN TRIALS (BULLETIN 225)

The testimony afforded by the records of the cows regularly enlisted in the maintenance trials *per se* can be greatly augmented by the use of the multitudinous data secured in the protein trials discussed in bulletin 225. Consequently all the available material used therein has been computed for the purposes of the maintenance trials in sections V, VI, VII and VIII in order to supplement the same. The cows whose records were thus employed were handled in the ordinary fashion, that is to say, they were served in due season with a view of annual calving. In this respect the conduct of the trials was unlike that of the maintenance experiment. However, since it has been shown, both at this Station and elsewhere, that fœtal construction as a matter of fact appears to make a relatively small direct draft upon the nutrient intake, not very much more than that involved in yielding 200 pounds of average milk, it seemed fair to segregate all the records, regardless of pregnancy or non-pregnancy. The number of separate records which contribute to this phase of the study—324—is impressive.

It was impracticable to make the week-by-week analysis of this vast number of records, as was done with those of the cows which were regularly enrolled in the maintenance trials, that is to say, to set forth the weekly usage of hay, grain and silage, or to indicate the varying live weights, milk and fat yields and nutrient usage as the feeding periods progressed. Furthermore, it was not thought necessary. All of the feeding was done in the barn, in the late fall, winter and early spring. It was, as a rule, reasonably uniform in respect to the character of the materials fed, the nutrient intakes and the milk yields. Both nutrient intakes and milk yields usually decreased progressively, changes in the ration being made quite commonly at five-week intervals. Live weights were bound to be affected in many cases by advancing pregnancy. To have calculated and printed this vast amount of material would have involved much extra labor in computation and many more pages of tabular matter. It is thought that this would have served no very necessary purpose. As it is, the re-computations of original data for the special purpose of this bulletin, upon which the tables on pp. 143 to 161 are based, involved many weeks of consecutive work. All the original data, and all the computation sheets, are kept in a fireproof vault and are available to anyone interested.

It seemed advisable, in presenting the results of this supplementary study, to group the data into separate classes, based, in the first place, on the ration fed, be it a very low-, a low-, a medium-, or a high-protein ration; and, in the second place, on the distance at the outset of the record from parturition on the one hand and service on the other. Thus we have four sub-divisions constructed on the basis of the nature of the rations fed, very low-, low-, medium-, and high-digestible protein, and five sub-divisions constructed on the basis of the immediate history of the several cows, the latter being as follows:

CLASS A. (Fresh, non-pregnant cows.) Fresh, within a month; unserved throughout the record period.

CLASS B. (Fresh cows.) Fresh within a month; unserved at the outset; not more than four months pregnant at close of the record period.

CLASS C. (Non-fresh, pregnant cows.) Two or more months in milk at the outset; four[1] or more months pregnant at close of the test period; making an average of more than 10 pounds of milk daily during the entire record period.

CLASS D. (Non-fresh, pregnant cows.) Same as C, except making 6 to 9.9 pounds milk daily.

CLASS E. (Non-fresh, pregnant cows.) Same as C, except making less than 6 pounds milk daily.

CLASS F. A single cow, persistently a shy breeder, farrow, and thrice in her second year of lactation.

The following statement indicates the distribution of the cows according to the two methods of distribution above referred to:

| Ration fed | Number of feeding periods | Classification | Number of feeding periods |
|---|---|---|---|
| Low protein ........ | 116 | Fresh; unserved during record period (Class A)......... | 84 |
| Medium protein ..... | 83 | Fresh; served during record period (Class B)......... | 94 |
| High protein ....... | 96 | Non-fresh; pregnant; making 10 or more pounds milk (Class C) ............... | 73 |
| Very low protein .... | 29 | Ditto; making 6 to 9.9 pounds milk (Class D) .......... | 53 |
| | | Ditto; making less than 6 pounds milk (Class E).... | 17 |
| | | A single shy breeder in second year of lactation (Class F) | 3 |
| | 324 | | 324 |

Pages 143 to 161 set forth the condensed data for these 324 records. It did not seem necessary to put headings at the top of each page. Furthermore, the extremely condensed form of the tabular matter and the fact that for each set of three horizontal lines the data in each of the three lines differs as to its nature, make it difficult to formulate headings; as difficult, for example, as it would be to indicate in a single phrase all that is going on at a given time in a three-ring circus. The only satisfactory method of meeting this situation would seem to be to set forth the headings once for all in the following paragraph:

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[1] With a few exceptions.

### EXPLANATION CONCERNING TABULAR MATTER, PAGES 143 TO 161

Each one of the 324 records contained in this tabular matter exhibits the following data: (the example referring to the first record occurring in table B).

I. *The initial caption* setting forth 6 items: The reference number in the given class (*1*); the cow's name (Ardelle); the year of her birth ('03); her breed and whether grade or registered (J)[1]; her age at the time the record was being made (6); the length of the record in terms of days (210).

II. *The upper horizontal line* setting forth 10 items: Months in milk at the opening of the record period (2); months in milk at its close (9); months since service at the opening of the record period (0); months since service at its close (3); average live weight in pounds (765); average daily digestible dry matter intake in pounds (16.15); average daily digestible protein intake in pounds (1.61); average daily milk yield in pounds (16.9); average daily fat yield in pounds (1.04); average fat percentage (6.15).

III. *The middle horizontal line* setting forth 8 items: The 1st 1.710, 3rd 1.938, 5th 1.912 and 7th 1.712, respectively, the average calculated daily digestible protein intake needed by a cow of the average weight indicated (765 pounds), giving the average daily milk yield indicated (16.9 pounds) of the average fat percentage indicated (6.15) at the nearest quarter percent, i. e., 6.25, according, respectively, to the Haecker, Savage, Eckles and Armsby standards; the 2nd, 13.94, 4th 14.03, 6th 13.62 and 8th 11.76, respectively, the average calculated daily digestible dry matter intake needed by the cow (765, 16.9, 6¼), according, respectively, to the Haecker, Savage, Eckles and Armsby standards.

IV. *The lower horizontal line* setting forth 8 items: The 1st, —6, 3rd —17, 5th —16 and 7th —6, respectively, the increase (+) or decrease (—), as the case may be, in the actual digestible protein intake of the cow (1.61 pounds) as compared with the several calculated intakes according to the Haecker, Savage, Eckles and Armsby standards, expressed as percentages, the standard in each instance equalling 100; the 2nd +16, 4th +15, 6th +24 and 8th +37, respectively, the increase (+) or decrease (—), as the case may be, in the actual digestible dry matter intake of the cow (16.15 pounds) as compared with the several calculated intakes according to the Haecker, Savage, Eckles and Armsby standards, expressed as percentages, the standard in each instance equalling 100 percent.

The whole proposition may be made yet more clear if the same example is set forth in narrative form:

I. *Caption.* Ardelle, a grade Jersey (J), dropped in 1903, when she was 6 years old was fed the low protein ration during 210. days of barn life in the late fall, winter and early spring.

II. *Upper horizontal line in the table.* She was 2 months along in lactation at the beginning and 9 months at the end of her record period and was served 3 months prior to its close. Her average live weight, her average daily digestible dry matter and digestible protein intakes, and her milk and fat yields were respectively, 765 pounds, 16.15 pounds, 1.61 pounds, 16.9 pounds and 1.04 pounds. Her milk averaged to test 6.15 percent fat.

III. *Middle horizontal line in the table.* The Haecker, Savage, Eckles and Armsby standards state that a cow of her average live weight giving 16.9 pounds of milk of 6¼ percent fat content, theoretically needs daily on the average for maintenance and milk making, respectively, 1.710, 1.938, 1.912 and 1.712 pounds of digestible protein and 13.94, 14.03, 13.62 and 11.76 pounds of digestible dry matter.

IV. *Lower horizontal line in the table.* Now, as a matter of fact, Ardelle's actual intakes of digestible protein and of digestible dry matter as compared with the calculated and theoretical intakes, according to the Haecker, Savage, Eckles and Armsby standards, in the order as stated, were greater or less than the standard by the following percentages: —6, —17, —16, —6; +16, +15, +19, +37.

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[1] J, grade Jersey; *J*, registered Jersey; H, grade Holstein; *A*, registered Ayrshire.

TABLE A.—LOW PROTEIN: 34 CLASS A RECORDS, AVERAGE LENGTH 137 DAYS

(*1*) Aggie, '99, J, 7, 175. (*2*) Aggie, '99, J, 9, 210. (*3*) Aggie, '99, J. 11, 210. (*4*) Aggie, '99, J, 13, 210. (*5*) Ardelle, '03, J, 9, 147. (*6*) Vt. Aster, '05, *J*, 6, 140. (7) Grace, '02, J, 6, 56. (*8*) Sheila, '02, J, 5, 91. (*9*) Sheila, '02, J, 8, 210. (*10*) Sheila, '02, J, 10, 77. (*11*) Sheila, '02, J, 12, 56. (*12*) Alta, '97, J, 14, 91. (*13*) Cherry, '00, J, 7, 175. (*14*) Dewdrop, '00, J, 10, 119. (*15*) Dewdrop, '00, J, 13, 217. (*16*) Elizabeth, '00, J, 12, 112. (*17*) Kate, '00, J, 8, 84. (*18*) Kate, '00, J, 13, 105. (*19*) Kinky, '10, J, 4, 217. (*20*) Ladybird, '00, J, 12, 133. (*21*) Laura B., '07, J, 5, 77. (*22*) Lena, '03, J, 6, 126. (*23*) Monetta, '06, *J*, 7, 140. (*24*) Vie, '02, J, 4, 175. (*25*) Zillah, '02, *A*, 7, 126. (*26*) Alice, '11, J, 5, 126. (*27*) Catrina 2nd, '10, HJ, 5, 161. (*28*) Grace, '02, J, 14, 168. (*29*) Sheila, '02, J, 11, 56. (*30*) Kinky, '10, J, 5, 84. (*31*) Kinky, '10, J, 7, 210. (*32*) Theta, '08, J, 9, 105. (*33*) Edith, '98, J, 11, 105. (*34*) Elizabeth, 00, J, 7, 175.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 1 | 6 | 0 | 0 | 873 | 16.07 | 1.725 | 23.1 | 1.09 | 4.72 |
| | | | 1.962 | 15.82 | 2.251 | 15.98 | 2.169 | 14.27 | 1.989 | 13.32 |
| | | | —12 | +2 | —23 | +1 | —20 | +13 | —13 | +21 |
| (*2*) | 0 | 7 | 0 | 0 | 917 | 20.17 | 2.033 | 14.7 | 1.23 | 4.98 |
| | | | 2.124 | 17.10 | 2.445 | 17.28 | 2.368 | 15.55 | 2.172 | 14.34 |
| | | | —4 | +18 | —17 | +17 | —14 | +30 | —6 | +41 |
| (*3*) | 2 | 9 | 0 | 0 | 923 | 16.01 | 1.719 | 19.2 | 0.90 | 4.69 |
| | | | 1.769 | 14.71 | 2.009 | 14.85 | 1.920 | 13.14 | 1.772 | 12.26 |
| | | | —3 | +9 | —14 | +8 | —10 | +22 | —3 | +31 |
| (*4*) | 3 | 10 | 0 | 0 | 829 | 13.75 | 1.386 | 16.7 | 0.80 | 4.76 |
| | | | 1.557 | 13.00 | 1.766 | 13.12 | 1.685 | 11.58 | 1.556 | 10.84 |
| | | | —11 | +6 | —22 | +5 | —18 | +19 | —11 | +27 |
| (*5*) | 0 | 5 | 0 | 0 | 774 | 14.63 | 1.666 | 27.8 | 1.43 | 5.15 |
| | | | 2.265 | 17.56 | 2.627 | 17.76 | 2.578 | 16.43 | 2.329 | 14.84 |
| | | | —26 | —17 | —37 | —18 | —35 | —11 | —28 | —1 |
| (*6*) | 0 | 4 | 0 | 0 | 853 | 12.96 | 1.450 | 19.6 | 0.95 | 4.85 |
| | | | 1.744 | 14.31 | 1.989 | 14.45 | 1.908 | 12.83 | 1.756 | 11.94 |
| | | | —17 | —9 | —27 | —10 | —24 | +1 | —17 | +9 |
| (7) | 0 | 2 | 0 | 0 | 860 | 16.57 | 1.768 | 28.0 | 1.30 | 4.64 |
| | | | 2.198 | 17.24 | 2.534 | 17.43 | 2.444 | 15.55 | 2.245 | 14.37 |
| | | | —20 | —4 | —30 | —5 | —28 | +7 | —21 | +15 |
| (*8*) | 0 | 3 | 0 | 0 | 777 | 14.41 | 1.517 | 23.2 | 1.05 | 4.53 |
| | | | 1.866 | 14.79 | 2.145 | 14.95 | 2.065 | 13.30 | 1.898 | 12.33 |
| | | | —19 | —3 | —29 | —4 | —26 | +8 | —20 | +17 |
| (*9*) | 3 | 10 | 0 | 0 | 893 | 14.97 | 1.657 | 19.6 | 1.15 | 5.87 |
| | | | 1.909 | 15.67 | 2.174 | 15.78 | 2.117 | 14.78 | 1.920 | 13.20 |
| | | | —13 | —4 | —24 | —5 | —22 | +1 | —14 | +13 |
| (*10*) | 0 | 2 | 0 | 0 | 858 | 14.29 | 1.597 | 25.5 | 1.14 | 4.47 |
| | | | 2.054 | 16.29 | 2.360 | 16.47 | 2.271 | 14.65 | 2.089 | 13.57 |
| | | | —22 | —12 | —32 | —13 | —30 | —2 | —24 | +5 |
| (*11*) | 1 | 2 | 0 | 0 | 815 | 12.30 | 1.465 | 29.2 | 1.29 | 4.45 |
| | | | 2.235 | 17.33 | 2.585 | 17.53 | 2.500 | 15.69 | 2.292 | 14.46 |
| | | | —34 | —29 | —43 | —30 | —41 | —22 | —36 | —15 |
| (*12*) | 0 | 3 | 0 | 0 | 906 | 14.99 | 1.880 | 21.9 | 1.05 | 4.79 |
| | | | 1.915 | 15.62 | 2.189 | 15.77 | 2.102 | 14.04 | 1.933 | 13.04 |
| | | | —2 | —4 | —14 | —5 | —11 | +7 | —3 | +15 |
| (*13*) | 0 | 5 | 0 | 0 | 816 | 14.90 | 1.566 | 17.0 | 0.82 | 4.82 |
| | | | 1.566 | 13.02 | 1.778 | 13.14 | 1.700 | 11.62 | 1.567 | 10.85 |
| | | | 0 | +15 | —12 | +13 | —8 | +28 | 0 | +38 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*14*) | 0 | 4 | 0 | 0 | 867 | 17.71 | 1.874 | 30.8 | 1.51 | 4.90 |
| | | 2.455 | | 19.13 | 2.855 | 19.35 | 2.789 | 17.60 | 2.531 | 16.10 |
| | | —24 | | —7 | —34 | —8 | —33 | +1 | —26 | +10 |
| (*15*) | 3 | 10 | 0 | 0 | 830 | 12.10 | 1.305 | 13.0 | 0.65 | 4.96 |
| | | 1.361 | | 11.76 | 1.530 | 11.85 | 1.453 | 10.44 | 1.346 | 9.80 |
| | | —4 | | +3 | —15 | +2 | —10 | +16 | —3 | +24 |
| (*16*) | 0 | 4 | 0 | 0 | 875 | 14.82 | 1.563 | 18.4 | 1.01 | 5.49 |
| | | 1.790 | | 14.74 | 2.029 | 14.87 | 1.965 | 13.62 | 1.791 | 12.39 |
| | | —13 | | +1 | —23 | 0 | —20 | +9 | —13 | +20 |
| (*17*) | 0 | 3 | 0 | 0 | 799 | 16.78 | 1.762 | 26.8 | 1.28 | 4.78 |
| | | 2.127 | | 16.65 | 2.462 | 16.84 | 2.309 | 15.16 | 2.181 | 13.95 |
| | | —17 | | +1 | —28 | 0 | —24 | +11 | —19 | +20 |
| (*18*) | 0 | 3 | 0 | 0 | 845 | 14.18 | 1.640 | 22.1 | 1.08 | 4.89 |
| | | 1.918 | | 15.50 | 2.205 | 15.65 | 2.133 | 14.07 | 1.948 | 13.00 |
| | | —14 | | —9 | —26 | —9 | —23 | +1 | —16 | +9 |
| (*19*) | 0 | 7 | 0 | 0 | 753 | 13.45 | 1.488 | 22.6 | 1.14 | 5.05 |
| | | 1.883 | | 14.97 | 2.177 | 15.12 | 2.115 | 13.67 | 1.927 | 12.57 |
| | | —21 | | —10 | —32 | —11 | —30 | —2 | —23 | +7 |
| (*20*) | 0 | 4 | 0 | 0 | 926 | 14.60 | 1.629 | 22.7 | 1.02 | 4.49 |
| | | 1.942 | | 15.79 | 2.215 | 15.95 | 2.119 | 14.09 | 1.955 | 13.14 |
| | | —16 | | —8 | —26 | —8 | —23 | +4 | —17 | +11 |
| (*21*) | 0 | 2 | 0 | 0 | 820 | 14.52 | 1.597 | 27.4 | 1.41 | 5.15 |
| | | 2.273 | | 17.76 | 2.629 | 17.96 | 2.575 | 16.56 | 2.331 | 14.99 |
| | | —30 | | —18 | —39 | —20 | —38 | —12 | —32 | —3 |
| (*22*) | 0 | 4 | 0 | 0 | 852 | 15.91 | 1.675 | 26.2 | 1.30 | 4.96 |
| | | 2.168 | | 17.18 | 2.509 | 17.37 | 2.439 | 15.70 | 2.222 | 14.43 |
| | | —23 | | —7 | —33 | —9 | —31 | +2 | —25 | +10 |
| (*23*) | 0 | 4 | 0 | 0 | 791 | 12.95 | 1.479 | 24.2 | 1.22 | 5.05 |
| | | 2.006 | | 15.90 | 2.320 | 16.07 | 2.256 | 14.54 | 2.055 | 13.36 |
| | | —26 | | —19 | —36 | —20 | —34 | —11 | —28 | —3 |
| (*24*) | 1 | 6 | 0 | 0 | 826 | 15.08 | 1.635 | 19.3 | 0.82 | 4.25 |
| | | 1.649 | | 13.46 | 1.871 | 13.59 | 1.789 | 11.92 | 1.651 | 11.15 |
| | | —1 | | +12 | —13 | +10 | —9 | +27 | —1 | +35 |
| (*25*) | 0 | 4 | 0 | 0 | 949 | 18.90 | 1.945 | 27.7 | 1.18 | 4.26 |
| | | 2.202 | | 17.44 | 2.520 | 17.64 | 2.427 | 15.58 | 2.230 | 14.47 |
| | | —12 | | +8 | —23 | +7 | —20 | +21 | —13 | +31 |
| (*26*) | 0 | 4 | 0 | 0 | *760* | 10.98 | 1.064 | 15.3 | 0.85 | 5.56 |
| | | 1.511 | | 12.51 | 1.710 | 12.62 | 1.654 | 11.53 | 1.508 | 10.52 |
| | | —30 | | —12 | —38 | —13 | —36 | —5 | —29 | +5 |
| (*27*) | 0 | 5 | 0 | 0 | *860* | 16.65 | 1.640 | 30.8 | 1.31 | 4.25 |
| | | 2.311 | | 17.85 | 2.666 | 18.06 | 2.583 | 16.06 | 2.362 | 14.83 |
| | | —29 | | —7 | —38 | —8 | —36 | +4 | —30 | +12 |
| (*28*) | 0 | 5 | 0 | 0 | *920* | 14.52 | 1.322 | 19.5 | 0.91 | 4.67 |
| | | 1.785 | | 14.80 | 2.029 | 14.94 | 1.939 | 13.23 | 1.789 | 12.34 |
| | | —26 | | —2 | —35 | —3 | —32 | +10 | —26 | +18 |
| (*29*) | 0 | 2 | 0 | 0 | 863 | 12.64 | 1.429 | 30.5 | 1.45 | 4.75 |
| | | 2.388 | | 18.59 | 2.770 | 18.80 | 2.692 | 16.95 | 2.455 | 15.57 |
| | | —40 | | —32 | —48 | —33 | —47 | —25 | —42 | —19 |
| (*30*) | 0 | 2 | 0 | 0 | *740* | 16.50 | 1.774 | 34.0 | 1.66 | 4.88 |
| | | 2.558 | | 19.40 | 3.000 | 19.64 | 2.949 | 18.02 | 2.665 | 16.37 |
| | | —31 | | —15 | —41 | —16 | —40 | —8 | —33 | +1 |
| (*31*) | 3 | 10 | 0 | 0 | *770* | 14.28 | 1.419 | 17.9 | 1.02 | 5.70 |
| | | 1.711 | | 13.95 | 1.953 | 14.05 | 1.907 | 12.50 | 1.766 | 11.76 |
| | | —17 | | +2 | —27 | +2 | —26 | +14 | —20 | +22 |
| (*32*) | 1 | 4 | 0 | 0 | *720* | 14.53 | 1.523 | 22.4 | 1.18 | 5.27 |
| | | 1.893 | | 14.92 | 2.184 | 15.07 | 2.134 | 13.86 | 1.934 | 12.57 |
| | | —20 | | —3 | —30 | —4 | —29 | +5 | —21 | +16 |
| (*33*) | 0 | 3 | 0 | 0 | 897 | 17.08 | 1.810 | 24.3 | 1.19 | 4.89 |
| | | 2.086 | | 16.78 | 2.402 | 16.95 | 2.326 | 15.26 | 2.123 | 14.08 |
| | | —13 | | +2 | —25 | +1 | —22 | +12 | —15 | +21 |
| (*34*) | 0 | 5 | 0 | 0 | 833 | 15.05 | 1.572 | 16.6 | 0.93 | 5.60 |
| | | 1.646 | | 13.64 | 1.861 | 13.76 | 1.799 | 12.57 | 1.641 | 11.46 |
| | | —4 | | +10 | —15 | +9 | —13 | +20 | —4 | +31 |

TABLE B.—LOW PROTEIN: 30 CLASS B RECORDS, AVERAGE LENGTH 160 DAYS

(*1*) Ardelle, '03, J, 6, 210. (*2*) Vt. Aster, '05, *J*, 5, 112. (*3*) Alta, '97, J, 9, 175. (*4*) Alta, '97, J, 11, 105. (*5*) Catrina 2nd, '10, HJ, 3, 224. (*6*) Cherry, '00, J, 11, 217. (*7*) Cherry, '00, J, 13, 224. (*8*) Crystal, '02, J, 4, 175. (*9*) Crystal, '02, J, 6, 161. (*10*) Crystal, '02, J, 8, 210. (*11*) Dewdrop, '00, J, 7, 210. (*12*) Crystal, '02, J, 10, 217. (*13*) Goldfinch, '01, J, 6, 203. (*14*) Hester, '01, J, 6, 105. (*15*) Hester, '01, J, 9, 210. (*16*) Kate, '00, J, 10, 140. (*17*) Ladybird, '00, J, 7, 133. (*18*) Ladybird, '00, J, 9, 147. (*19*) Lena, '03, J, 3, 133. (*20*) Santa Rosa, '99, J, 9, 119. (*21*) Theta, '08, J, 5, 210. (*22*) Catrina 2nd, '10, HJ, 6, 105. (*23*) Theta, '08, J, 7, 126. (*24*) Vt. Una 2nd, '11, *J*, 3, 161. (*25*) Ardelle, '03, J, 7, 168. (*26*) Ardelle, '03, J, 8, 168. (*27*) Vie, '02, J, 7, 210. (*28*) Elizabeth, '00, J, 8, 119. (*29*) Elizabeth, '00, J, 10, 112. (*30*) Zillah, '02, *A*, 5, 91.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 2 | 9 | 0 | 3 | 765 | 16.15 | 1.610 | 16.9 | 1.04 | 6.15 |
| | | | 1.710 | 13.94 | 1.938 | 14.03 | 1.912 | 13.62 | 1.712 | 11.76 |
| | | | —6 | +16 | —17 | +15 | —16 | +19 | —6 | +37 |
| (*2*) | 0 | 4 | 0 | 1 | 894 | 14.74 | 1.697 | 20 | 1.00 | 5.00 |
| | | | 1.826 | 15.05 | 2.086 | 15.19 | 2.008 | 13.57 | 1.841 | 12.59 |
| | | | —7 | —2 | —19 | —3 | —15 | +9 | —8 | +17 |
| (*3*) | 2 | 7 | 0 | 3 | 872 | 13.45 | 1.425 | 19.3 | 1.00 | 5.18 |
| | | | 1.807 | 14.85 | 2.058 | 14.98 | 1.988 | 13.58 | 1.816 | 12.46 |
| | | | —21 | —9 | —31 | —10 | —28 | —1 | —22 | +8. |
| (*4*) | 0 | 3 | 0 | 1 | 835 | 16.90 | 1.705 | 22.6 | 1.14 | 5.05 |
| | | | 1.986 | 15.91 | 2.280 | 16.07 | 2.219 | 14.69 | 2.017 | 13.39 |
| | | | —14 | +6 | —25 | +5 | —23 | +15 | —15 | +26 |
| (*5*) | 1 | 8 | 0 | 1 | 879 | 15.01 | 1.661 | 24.6 | 1.08 | 4.39 |
| | | | 2.018 | 16.12 | 2.313 | 16.29 | 2.222 | 14.46 | 2.045 | 13.42 |
| | | | —18 | —7 | —28 | —8 | —25 | +4 | —19 | +12 |
| (*6*) | 1 | 8 | 0 | 6 | 923 | 12.63 | 1.435 | 14.9 | 0.70 | 4.70 |
| | | | 1.518 | 13.06 | 1.704 | 13.16 | 1.612 | 11.53 | 1.498 | 10.86 |
| | | | —5 | —3 | —16 | —4 | —11 | +10 | —4 | +16 |
| (*7*) | 1 | 8 | 0 | 4 | 888 | 12.70 | 1.270 | 14.7 | 0.67 | 4.56 |
| | | | 1.148 | 10.53 | 1.258 | 10.59 | 1.175 | 9.24 | 1.099 | 8.75 |
| | | | +10 | +21 | +1 | +20 | +8 | +37 | +16 | +45 |
| (*8*) | 0 | 5 | 0 | 2 | 774 | 14.52 | 1.514 | 17.8 | 0.89 | 5.00 |
| | | | 2.015 | 16.17 | 2.321 | 16.34 | 2.249 | 14.71 | 2.054 | 13.56 |
| | | | —25 | —10 | —35 | —11 | —33 | —1 | —26 | +7 |
| (*9*) | 0 | 5 | 0 | 1 | 855 | 17.98 | 1.864 | 23.6 | 1.17 | 4.96 |
| | | | 1.582 | 13.33 | 1.794 | 13.45 | 1.717 | 11.93 | 1.580 | 11.14 |
| | | | +18 | +35 | +4 | +34 | +9 | +51 | +18 | +62 |
| (*10*) | 1 | 8 | 0 | 6 | 863 | 14.43 | 1.590 | 16.3 | 0.82 | 5.03 |
| | | | 1.979 | 15.80 | 2.274 | 15.96 | 2.215 | 14.60 | 2.012 | 13.30 |
| | | | —20 | —9 | —30 | —10 | —28 | —1 | —21 | +8 |
| (*11*) | 1 | 8 | 0 | 1 | 816 | 15.47 | 1.493 | 22.7 | 1.19 | 5.24 |
| | | | 1.418 | 12.21 | 1.597 | 12.30 | 1.518 | 10.84 | 1.403 | 10.18 |
| | | | +5 | +27 | —7 | +26 | —2 | +43 | +7 | +52 |
| (*12*) | 1 | 8 | 0 | 4 | 852 | 12.24 | 1.212 | 13.7 | 0.69 | 5.05 |
| | | | 1.829 | 14.89 | 2.089 | 15.03 | 2.023 | 13.66 | 1.845 | 12.51 |
| | | | —34 | —18 | —42 | —19 | —40 | —10 | —34 | —2 |
| (*13*) | 1 | 7 | 0 | 1 | 841 | 15.57 | 1.528 | 20 | 1.07 | 5.35 |
| | | | 1.839 | 14.98 | 2.103 | 15.13 | 2.019 | 13.46 | 1.859 | 12.50 |
| | | | —17 | +4 | —27 | +3 | —24 | +16 | —18 | +25 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (14) | 1 | 4 | 0 | 1 | 864 | 14.41 | 1.476 | 21.1 | 1.00 | 4.74 |
| | | 1.985 | | 16.16 | 2.258 | 16.31 | 2.194 | 15.00 | 1.994 | 13.60 |
| | | —26 | | —11 | —35 | —12 | —33 | —4 | —26 | +6 |
| (15) | 1 | 8 | 0 | 3 | 915 | 15.25 | 1.652 | 21 | 1.14 | 5.43 |
| | | 2.160 | | 17.24 | 2.482 | 17.42 | 2.418 | 15.94 | 2.196 | 14.52 |
| | | —24 | | —12 | —33 | —12 | —32 | —4 | —25 | +5 |
| (16) | 0 | 5 | 0 | 1 | 889 | 16.29 | 1.979 | 24.8 | 1.33 | 5.36 |
| | | 2.130 | | 17.31 | 2.434 | 17.47 | 2.360 | 15.89 | 2.150 | 14.55 |
| | | —7 | | —6 | —19 | —7 | —16 | +2 | —8 | +12 |
| (17) | 0 | 4 | 0 | 2 | 970 | 18.33 | 1.828 | 23.4 | 1.20 | 5.13 |
| | | 2.199 | | 17.74 | 2.508 | 17.91 | 2.443 | 16.53 | 2.217 | 14.94 |
| | | —17 | | +3 | —27 | +2 | —25 | +11 | —18 | +23 |
| (18) | 0 | 5 | 0 | 1 | 965 | 19.88 | 2.095 | 23.8 | 1.29 | 5.42 |
| | | 1.661 | | 13.63 | 1.900 | 13.76 | 1.831 | 12.31 | 1.677 | 11.41 |
| | | +26 | | +47 | +10 | +45 | +14 | +62 | +25 | +74 |
| (19) | 0 | 4 | 0 | 1 | 795 | 14.17 | 1.504 | 18.4 | 0.93 | 5.05 |
| | | 1.710 | | 14.17 | 1.930 | 14.30 | 1.838 | 12.49 | 1.701 | 11.72 |
| | | —12 | | 0 | —22 | —1 | —18 | +13 | —12 | +21 |
| (20) | 0 | 4 | 0 | 1 | 920 | 15.55 | 1.538 | 19.2 | 0.80 | 4.17 |
| | | 1.821 | | 14.64 | 2.087 | 14.76 | 2.046 | 13.95 | 1.845 | 12.36 |
| | | —16 | | +6 | —26 | +5 | —25 | +11 | —17 | +26 |
| (21) | 0 | 7 | 0 | 2 | 758 | 12.55 | 1.424 | 19.7 | 1.13 | 5.74 |
| | | 2.313 | | 17.89 | 2.666 | 18.10 | 2.581 | 16.08 | 2.363 | 14.85 |
| | | —38 | | —30 | —47 | —31 | —45 | —22 | —40 | —15 |
| (22) | 0 | 3 | 0 | 2 | 870 | 20.55 | 2.000 | 30.7 | 1.28 | 4.17 |
| | | 2.029 | | 15.86 | 2.358 | 16.04 | 2.301 | 14.57 | 2.090 | 13.34 |
| | | —1 | | +30 | —15 | +28 | —13 | +41 | —4 | +54 |
| (23) | 0 | 4 | 0 | 1 | 730 | 12.65 | 1.310 | 25.3 | 1.26 | 4.98 |
| | | 1.601 | | 13.11 | 1.818 | 13.22 | 1.763 | 12.15 | 1.605 | 11.02 |
| | | —18 | | —4 | —28 | —4 | —26 | +4 | —18 | +15 |
| (24) | 0 | 5 | 0 | 2 | 760 | 13.60 | 1.391 | 16.7 | 0.90 | 5.39 |
| | | 1.460 | | 12.51 | 1.636 | 12.61 | 1.543 | 11.00 | 1.438 | 10.37 |
| | | —5 | | +9 | —15 | +8 | —10 | +24 | —3 | +31 |
| (25) | 0 | 7 | 0 | 3 | 767 | 18.86 | 1.869 | 24.3 | 1.35 | 5.56 |
| | | 2.092 | | 16.39 | 2.408 | 16.56 | 2.364 | 15.47 | 2.134 | 13.84 |
| | | —11 | | +15 | —22 | +14 | —21 | +22 | —12 | +36 |
| (26) | 0 | 6 | 0 | 2 | 806 | 16.22 | 1.821 | 24.1 | 1.27 | 5.27 |
| | | 2.058 | | 16.30 | 2.372 | 16.47 | 2.315 | 15.12 | 2.099 | 13.73 |
| | | —12 | | 0 | —23 | —2 | —21 | +7 | —13 | +18 |
| (27) | 1 | 8 | 0 | 5 | 989 | 17.52 | 1.905 | 23.1 | 0.94 | 4.07 |
| | | 1.940 | | 15.77 | 2.194 | 15.93 | 2.100 | 13.89 | 1.935 | 13.02 |
| | | —2 | | +11 | —13 | +10 | —9 | +26 | —2 | +35 |
| (28) | 0 | 4 | 0 | 1 | 881 | 18.92 | 2.043 | 23.7 | 1.24 | 5.23 |
| | | 2.086 | | 16.73 | 2.394 | 16.89 | 2.300 | 15.44 | 2.118 | 14.08 |
| | | —2 | | +13 | —15 | +12 | —11 | +23 | —4 | +34 |
| (29) | 0 | 4 | 0 | 1 | 900 | 17.00 | 1.965 | 22.8 | 1.22 | 5.35 |
| | | 2.044 | | 16.51 | 2.340 | 16.67 | 2.272 | 15.19 | 2.069 | 13.89 |
| | | —4 | | +3 | —16 | +2 | —13 | +12 | —5 | +23 |
| (30) | 0 | 3 | 0 | 1 | 897 | 14.94 | 1.571 | 24.3 | 1.03 | 4.24 |
| | | 1.976 | | 15.81 | 2.256 | 15.98 | 2.167 | 14.08 | 1.994 | 13.11 |
| | | —21 | | —6 | —30 | —7 | —27 | +6 | —21 | +14 |

CLASS C.—MEDIUM PROTEIN: 18 CLASS A RECORDS, AVERAGE LENGTH 142 DAYS

(*1*) Angie, '04, J, 5, 210. (*2*) Elbaje, ?, H, 7, 98. (*3*) Elbaje, ?, H, 10, 147. (*4*) Lizzie Hexam, '99, J, 9, 168. (*5*) Slicker, '99, J, 9, 126. (*6*) Slicker, '99, J, 13, 210. (7) Avis, '06, J, 9, 133. (*8*) Edith, '98, J, 9, 175. (*9*) Edith, '98, J, 13, 182. (*10*) Fatima, '02, J, 5, 175. (*11*) Goldfinch, '01, J, 8, 126. (*12*) Laura B, '07, J, 6, 49. (*13*) Tansy, '03, J, 11, 224. (*14*) Angie, '04, J, 8, 70. (*15*) Elizabeth, '00, J, 7, 91. (*16*) Elizabeth, '00, J, 9, 105. (*17*) Elizabeth, '00, J, 11, 133. (*18*) Tansy, '03, J, 6, 126.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 0 | 7 | 0 | 0 | 926 | 18.15 | 2.235 | 17.8 | 1.14 | 6.41 |
| | | 1.930 | | 15.89 | 2.161 | 15.96 | 2.139 | 15.61 | 1.907 | 13.39 |
| | | +16 | | +14 | +3 | +14 | +4 | +16 | +17 | +36 |
| (*2*) | 0 | 3 | 0 | 0 | 1180 | 17.76 | 2.653 | 36.2 | 1.27 | 3.51 |
| | | 2.600 | | 20.69 | 3.034 | 20.90 | 2.942 | 18.59 | 2.641 | 16.95 |
| | | +2 | | —14 | —13 | —15 | —10 | —4 | 0 | +5 |
| (*3*) | 0 | 5 | 0 | 0 | 1188 | 17.52 | 2.558 | 33.6 | 1.22 | 3.63 |
| | | 2.478 | | 19.94 | 2.881 | 20.14 | 2.786 | 17.85 | 2.506 | 16.33 |
| | | +3 | | —12 | —11 | —13 | —8 | —2 | +2 | +7 |
| (*4*) | 0 | 5 | 0 | 0 | 1002 | 14.60 | 1.982 | 20.3 | 0.89 | 4.38 |
| | | 1.859 | | 15.50 | 2.102 | 15.64 | 1.998 | 13.73 | 1.852 | 12.87 |
| | | +7 | | —6. | —6 | —7 | —1 | +6 | +7 | +14 |
| (*5*) | 0 | 4 | 0 | 0 | 903 | 15.33 | 1.992 | 21.2 | 0.96 | 4.53 |
| | | 1.841 | | 15.05 | 2.095 | 15.20 | 2.001 | 13.41 | 1.849 | 12.51 |
| | | +8 | | +2 | —5 | +1 | 0 | +14 | +8 | +23 |
| (*6*) | 0 | 7 | 0 | 0 | 933 | 14.35 | 2.096 | 13.7 | 0.66 | 4.82 |
| | | 1.455 | | 12.67 | 1.626 | 12.77 | 1.533 | 11.15 | 1.427 | 10.53 |
| | | +44 | | +13 | +29 | +12 | +37 | +29 | +47 | +36 |
| (7) | 0 | 4 | 0 | 0 | 792 | 17.72 | 2.293 | 27.6 | 1.35 | 4.90 |
| | | 2.210 | | 17.27 | 2.569 | 17.46 | 2.507 | 15.86 | 2.278 | 14.53 |
| | | +4 | | +3 | —11 | +2 | —9 | +12 | +1 | +22 |
| (*8*) | 0 | 5 | 0 | 0 | 843 | 15.00 | 2.145 | 21.1 | 1.05 | 4.98 |
| | | 1.856 | | 15.08 | 2.130 | 15.23 | 2.059 | 13.67 | 1.882 | 12.64 |
| | | +16 | | —1 | +1 | —2 | +4 | +10 | +14 | +19 |
| (*9*) | 0 | 6 | 0 | 0 | 874 | 16.15 | 2.407 | 25.1 | 1.22 | 4.87 |
| | | 2.080 | | 16.59 | 2.394 | 16.77 | 2.313 | 15.02 | 2.118 | 13.88 |
| | | +15 | | —3 | +1 | —4 | +4 | +8 | +14 | +16 |
| (*10*) | 3 | 8 | 0 | 0 | 932 | 14.34 | 1.840 | 12.0 | 0.79 | 6.52 |
| | | 1.516 | | 13.15 | 1.672 | 13.20 | 1.626 | 12.52 | 1.469 | 11.03 |
| | | +21 | | +9 | +10 | +9 | +13 | +15 | +25 | +30 |
| (*11*) | 0 | 4 | 0 | 0 | 896 | 18.84 | 2.548 | 26.4 | 1.43 | 5.42 |
| | | 2.317 | | 18.30 | 2.660 | 18.48 | 2.607 | 17.21 | 2.355 | 15.44 |
| | | +10 | | +4. | +4 | +2 | —2 | +9 | +8 | +22 |
| (*12*) | 0 | 1 | 0 | 0 | 872 | 15.51 | 2.327 | 34.3 | 1.78 | 5.19 |
| | | 2.737 | | 21.01 | 3.183 | 21.25 | 3.130 | 19.73 | 2.825 | 17.77 |
| | | —15 | | —27 | —27 | —27 | —26 | —21 | —18 | —13 |
| (*13*) | 4 | 11 | 0 | 0 | 902 | 11.05 | 1.402 | 11.8 | 0.65 | 5.45 |
| | | 1.387 | | 12.16 | 1.541 | 12.25 | 1.463 | 10.95 | 1.352 | 10.16 |
| | | +1 | | —9 | —9 | —10 | —4 | +1 | +4 | +9 |
| (*14*) | 0 | 2 | 0 | 0 | 1083 | 14.19 | 2.086 | 31.1 | 1.87 | 6.01 |
| | | 2.842 | | 22.61 | 3.278 | 22.80 | 3.233 | 22.13 | 2.902 | 19.14 |
| | | —27 | | —37 | —36 | —38 | —35 | —36 | —28 | —26 |
| (*15*) | 0 | 3 | 0 | 1 | 823 | 16.66 | 2.363 | 23.7 | 1.28 | 5.40 |
| | | 2.093 | | 16.57 | 2.401 | 16.74 | 2.350 | 15.57 | 2.124 | 13.98 |
| | | +13 | | +1 | —2 | 0 | +1 | +7 | +11 | +19 |
| (*16*) | 0 | 3 | 0 | 1 | 887 | 18.78 | 2.600 | 25.2 | 1.40 | 5.56 |
| | | 2.234 | | 17.72 | 2.561 | 17.90 | 2.506 | 16.63 | 2.266 | 14.95 |
| | | +16 | | +6 | +2 | +5 | +4 | +13 | +15 | +26 |
| (*17*) | 0 | 4 | 0 | 1 | 848 | 14.65 | 2.130 | 22.7 | 1.20 | 5.29 |
| | | 2.001 | | 16.05 | 2.296 | 16.21 | 2.233 | 14.81 | 2.030 | 13.51 |
| | | +6 | | —9 | —7 | —10 | —5 | —2 | +5 | +8 |
| (*18*) | 0 | 4 | 0 | 1 | 920 | 17.77 | 2.280 | 22.1 | 1.21 | 5.48 |
| | | 2.058 | | 16.67 | 2.346 | 16.82 | 2.283 | 15.50 | 2.072 | 14.02 |
| | | +11 | | +7 | —3 | +6 | 0 | +15 | +10 | +27 |

TABLE D.—MEDIUM PROTEIN: 29 CLASS B RECORDS, AVERAGE LENGTH 182 DAYS

(*1*) Avis, '00, J, 14, 119. (*2*) Elbaje, ?, H, 10, 203. (*3*) Karah, '09, J, 4, 119. (*4*) Lizzie Hexam, '99, J, 7, 175. (*5*) Lizzie Hexam, '99, J, 10, 210. (*6*) Lizzie Hexam, '99, J, 11, 210. (*7*) Lizzie Hexam, '99, J, 12, 196. (*8*) Rocket, '05, J, 5, 210. (*9*) Rocket, '05, J, 6, 210. (*10*) Rocket, '05, J, 8, 217. (*11*) Slicker, '99, J, 7, 175. (*12*) Vt. Ivis, '08, *J*, 5, 175. (*13*) Avis, '00, J, 6, 175. (*14*) Crystal, '02, J, 5, 147. (*15*) Crystal, '02, J, 9, 217. (*16*) Crystal, '02, J, 11, 217. (*17*) Doris, '01, J, 6, 119. (*18*) Doris, '01, J, 10, 217. (*19*) Goldfinch, '01, J, 5, 175. (*20*) Ladybird, '00, J, 6, 175. (*21*) Ladybird, '00, J, 8, 140. (*22*) Ladybird, '00, J, 10, 140. (*23*) Mildred, '03, J, 10, 217. (*24*) Tansy, '03, J, 3, 175. (*25*) Tansy, '03, J, 7, 119. (*26*) Theta, '08, J, 4, 203. (*27*) Zillah, '02, *A*, 6, 105. (*28*) Vt. Una, '00, *J*, 12, 217. (*29*) Angie, '04, J, 3, 210.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 0 | 5 | 0 | 3 | 834 | 21.47 | 3.03 | 33.3 | 1.52 | 4.57 |
| | | | 2.482 | 19.00 | 2.882 | 19.23 | 2.795 | 17.27 | 2.557 | 15.87 |
| | | | +22 | +13 | +5 | +12 | +8 | +24 | +18 | +35 |
| (*2*) | 0 | 7 | 0 | 2 | 1218 | 19.09 | 2.768 | 32.6 | 1.19 | 3.65 |
| | | | 2.450 | 19.86 | 2.841 | 20.05 | 2.743 | 17.75 | 2.471 | 16.27 |
| | | | +13 | —4 | —3 | —5 | +1 | +8 | +12 | +17 |
| (*3*) | 0 | 4 | 0 | 2 | 827 | 13.42 | 2.034 | 23.7 | 1.23 | 5.19 |
| | | | 2.048 | 16.30 | 2.356 | 16.46 | 2.298 | 15.09 | 2.086 | 13.73 |
| | | | —1 | —18 | —14 | —18 | —11 | —11 | —2 | —2 |
| (*4*) | 4 | 9 | 0 | 3 | 960 | 14.28 | 1.830 | 15.1 | 0.71 | 4.70 |
| | | | 1.553 | 13.43 | 1.744 | 13.53 | 1.649 | 11.85 | 1.533 | 11.16 |
| | | | +18 | +6 | +5 | +5 | +11 | +20 | +19 | +28 |
| (*5*) | 1 | 8 | 0 | 5 | 1045 | 17.25 | 2.348 | 20.5 | 0.96 | 4.70 |
| | | | 1.931 | 16.18 | 2.187 | 16.32 | 2.085 | 14.41 | 1.928 | 13.48 |
| | | | +22 | +7 | +7 | +6 | +13 | +20 | +22 | +28 |
| (*6*) | 1 | 8 | 0 | 4 | 1015 | 15.52 | 2.222 | 18.6 | 0.84 | 4.55 |
| | | | 1.771 | 14.97 | 1.994 | 15.10 | 1.888 | 13.20 | 1.755 | 12.42 |
| | | | +25 | +4 | +11 | +3 | +18 | +18 | +27 | +25 |
| (7) | 0 | 6 | 0 | 0 | 1004 | 15.97 | 2.322 | 17.7 | 0.82 | 4.65 |
| | | | 1.712 | 14.55 | 1.924 | 14.67 | 1.820 | 12.81 | 1.693 | 12.07 |
| | | | +36 | +10 | +21 | +9 | +28 | +25 | +37 | +32 |
| (*8*) | 1 | 8 | 0 | 7 | 1094 | 16.54 | 2.329 | 19.0 | 1.09 | 5.75 |
| | | | 2.010 | 17.00 | 2.267 | 17.11 | 2.188 | 15.81 | 1.996 | 14.27 |
| | | | +16 | —3 | +3 | —3 | +6 | +5 | +17 | +16 |
| (*9*) | 1 | 8 | 0 | 6 | 1088 | 13.69 | 1.900 | 14.6 | 0.85 | 5.82 |
| | | | 1.718 | 15.02 | 1.925 | 15.11 | 1.829 | 13.76 | 1.681 | 12.57 |
| | | | +11 | —9 | —1 | —9 | +4 | —1 | +13 | +9 |
| (*10*) | 1 | 8 | 0 | 4 | 1110 | 14.07 | 1.987 | 17.7 | 0.99 | 5.60 |
| | | | 1.910 | 16.31 | 2.140 | 16.43 | 2.051 | 14.84 | 1.881 | 13.65 |
| | | | +4 | —14 | —7 | —14 | —3 | —5 | +6 | +3 |
| (*11*) | 0 | 5 | 0 | 1 | 896 | 15.71 | 2.115 | 20.3 | 0.97 | 4.78 |
| | | | 1.810 | 14.92 | 2.069 | 15.06 | 1.982 | 13.37 | 1.826 | 12.45 |
| | | | +17 | +5 | +2 | +5 | +7 | +17 | +16 | +26 |
| (*12*) | 2 | 7 | 0 | 3 | 780 | 13.00 | 1.789 | 16.2 | 0.82 | 5.06 |
| | | | 1.518 | 12.63 | 1.729 | 12.75 | 1.659 | 11.35 | 1.524 | 10.57 |
| | | | +18 | +3 | +3 | +2 | +8 | +14 | +17 | +23 |
| (*13*) | 0 | 5 | 0 | 3 | 762 | 14.79 | 2.240 | 22.1 | 1.07 | 4.84 |
| | | | 1.826 | 14.55 | 2.103 | 14.71 | 2.032 | 13.17 | 1.860 | 12.17 |
| | | | +23 | +2 | +7 | +1 | +10 | +12 | +20 | +21 |
| (*14*) | 0 | 5 | 0 | 2 | 826 | 15.66 | 2.150 | 20.0 | 1.00 | 5.00 |
| | | | 1.778 | 14.51 | 2.038 | 14.65 | 1.968 | 13.13 | 1.801 | 12.15 |
| | | | +21 | +8 | +5 | +7 | +11 | +19 | +21 | +29 |
| (*15*) | 1 | 8 | 0 | 6 | 869 | 12.95 | 1.778 | 17.6 | 0.90 | 5.11 |
| | | | 1.734 | 13.90 | 1.963 | 14.02 | 1.815 | 12.50 | 1.669 | 11.62 |
| | | | +3 | —7 | —9 | —8 | —2 | +4 | +7 | +12 |
| (*16*) | 0 | 7 | 0 | 2 | 846 | 12.97 | 1.830 | 17.6 | 0.85 | 4.83 |
| | | | 1.622 | 13.49 | 1.842 | 13.61 | 1.759 | 12.04 | 1.624 | 11.23 |
| | | | +13 | —4 | —1 | —5 | +4 | +8 | +13 | +16 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*17*) | 0 | 4 | 0 | 1 | 865 | 15.17 | 2.185 | 23.7 | 1.12 | 4.13 |
| | | | 1.921 | 15.34 | 2.193 | 15.51 | 2.109 | 13.67 | 1.940 | 12.72 |
| | | | +14 | —1 | 0 | —2 | +4 | +11 | +13 | +19 |
| (*18*) | 3 | 10 | 0 | 4 | 963 | 12.38 | 1.655 | 13.5 | 0.68 | 5.04 |
| | | | 1.484 | 13.01 | 1.660 | 13.10 | 1.569 | 11.49 | 1.457 | 10.83 |
| | | | +12 | —5 | 0 | —5 | +5 | +8 | +14 | +14 |
| (*19*) | 0 | 5 | 0 | 4 | 821 | 14.40 | 1.927 | 13.6 | 0.83 | 6.11 |
| | | | 1.486 | 12.64 | 1.676 | 12.73 | 1.622 | 11.93 | 1.476 | 10.62 |
| | | | +29 | +14 | +15 | +13 | +19 | +21 | +21 | +36 |
| (*20*) | 0 | 5 | 0 | 2 | 893 | 15.07 | 2.070 | 16.1 | 0.87 | 5.40 |
| | | | 1.666 | 13.99 | 1.865 | 14.02 | 1.795 | 12.74 | 1.642 | 11.66 |
| | | | +24 | +8 | +11 | +7 | +15 | +18 | +26 | +29 |
| (*21*) | 1 | 5 | 0 | 2 | 969 | 19.77 | 2.665 | 25.9 | 1.40 | 5.41 |
| | | | 2.336 | 18.67 | 2.673 | 18.85 | 2.611 | 17.47 | 2.464 | 15.73 |
| | | | +14 | +6 | 0 | +5 | +2 | +13 | +8 | +26 |
| (*22*) | 0 | 5 | 0 | 1 | 965 | 18.30 | 2.680 | 23.9 | 1.27 | 5.31 |
| | | | 2.157 | 17.48 | 2.468 | 17.64 | 2.395 | 16.07 | 2.182 | 14.69 |
| | | | +24 | +5 | +9 | +4 | +12 | +14 | +23 | +25 |
| (*23*) | 1 | 8 | 0 | 5 | 853 | 13.52 | 1.818 | 16.4 | 0.80 | 4.88 |
| | | | 1.581 | 13.29 | 1.794 | 13.41 | 1.716 | 11.90 | 1.581 | 11.10 |
| | | | +15 | +2 | +1 | +1 | +6 | +14 | +15 | +22 |
| (*24*) | 1 | 6 | 0 | 1 | 830 | 15.62 | 2.195 | 19.7 | 1.05 | 5.33 |
| | | | 1.802 | 14.68 | 2.059 | 14.82 | 1.994 | 13.46 | 1.818 | 12.34 |
| | | | +22 | +6 | +7 | +5 | +10 | +16 | +21 | +27 |
| (*25*) | 0 | 4 | 0 | 2 | 949 | 15.82 | 2.446 | 22.7 | 1.19 | 5.24 |
| | | | 2.072 | 16.86 | 2.367 | 17.02 | 2.294 | 15.47 | 2.090 | 14.16 |
| | | | +18 | —6 | +3 | —7 | +7 | +2 | +17 | +12 |
| (*26*) | 1 | 7 | 0 | 4 | 761 | 14.20 | 2.055 | 21.4 | 1.22 | 5.70 |
| | | | 1.934 | 15.41 | 2.223 | 15.54 | 2.184 | 14.76 | 1.967 | 13.02 |
| | | | +7 | —8 | —8 | —9 | —6 | —4 | +4 | +9 |
| (*27*) | 0 | 3 | 0 | 1 | 934 | 16.97 | 2.390 | 28.0 | 1.13 | 4.04 |
| | | | 2.166 | 17.01 | 2.474 | 17.21 | 2.389 | 15.12 | 2.188 | 14.06 |
| | | | +10 | 0 | —3 | —1 | 0 | +12 | +9 | +21 |
| (*28*) | 2 | 9 | 0 | 2 | 834 | 11.71 | 1.480 | 12.7 | 0.66 | 5.20 |
| | | | 1.371 | 11.83 | 1.536 | 11.92 | 1.463 | 10.61 | 1.350 | 9.89 |
| | | | +9 | —1 | —4 | —2 | +1 | +10 | +10 | +18 |
| (*29*) | 2 | 9 | 0 | 4 | 858 | 13.65 | 1.748 | 14.7 | 0.91 | 6.19 |
| | | | 1.622 | 13.65 | 1.821 | 13.73 | 1.778 | 13.10 | 1.603 | 11.48 |
| | | | +8 | 0 | —4 | —1 | —2 | +4 | +9 | +19 |

### TABLE E.—HIGH PROTEIN: 26 CLASS A RECORDS, AVERAGE LENGTH 140 DAYS

(*1*) Cassandra, '01, J, 7, 175. (*2*) Catrina, ?, H, 6, 98. (*3*) Catrina, ?, H, 7, 84. (*4*) Beatrice, '12, J, 2, 112. (*5*) Electa, '09, J, 5, 119. (*6*) Hilda, '01, J, 6, 175. (*7*) Rosel, '96, J, 13, 168. (*8*) Rosel, '96, J, 16, 147. (*9*) Vic, '10, J, 4, 203. (*10*) Yuba, '99, J, 8, 175. (*11*) Yuba, '99, J, 9, 56. (*12*) Zeta, '99, J, 11, 154. (*13*) Alta, '97, J, 13, 119. (*14*) Cherry, '00, J, 8, 91. (*15*) Dewdrop, '00, J, 14, 70. (*16*) Doris, '01, J, 8, 119. (*17*) Doris, '01, J, 13, 224. (*18*) Fatima '02, J, 6, 77. (*19*) Hester, '01, J, 8, 126. (*20*) Kate, '00, J, 7, 175. (*21*) Perusia Lady, '03, *J*, 4, 175. (*22*) Santa Rosa, '99, J, 10, 119. (*23*) Tansy, '03, J, 7, 91. (*24*) Madam, '05, J, 7, 196. (*25*) Vt. Una, '00, *J*, 7, 161. (*26*) Mildred, '03, J, 10, 224.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 4 | 9 | 0 | 0 | 833 | 16.18 | 2.640 | 18.0 | 0.95 | 5.28 |
| | | | 1.699 | 14.00 | 1.933 | 14.13 | 1.867 | 12.78 | 1.705 | 11.75 |
| | | | +55 | +16 | +37 | +15 | +41 | +27 | +55 | +38 |
| (*2*) | 0 | 3 | 0 | 0 | 1049 | 21.96 | 4.040 | 53.1 | 1.72 | 3.24 |
| | | | 3.280 | 24.19 | 3.867 | 24.41 | 3.846 | 22.33 | 3.403 | 19.81 |
| | | | +23 | —9 | +4 | —10 | +5 | —2 | +19 | +11 |
| (*3*) | 0 | 2 | 0 | 0 | 1070 | 22.17 | 3.774 | 46.5 | 1.39 | 2.99 |
| | | | 2.935 | 21.69 | 3.400 | 21.83 | 3.403 | 19.99 | 3.016 | 17.68 |
| | | | +29 | +2 | +11 | +2 | +11 | +11 | +25 | +25 |
| (*4*) | 0 | 3 | 0 | 0 | 1093 | 15.83 | 2.972 | 27.4 | 1.25 | 4.56 |
| | | | 2.327 | 18.86 | 2.656 | 19.05 | 2.540 | 16.84 | 2.345 | 15.69 |
| | | | +28 | —16 | +12 | —17 | +17 | —6 | +27 | +1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*5*) | 0 | 4 | 0 | 0 | 832 | 14.44 | 2.664 | 23.8 | 1.27 | 5.34 |
| | | 2.058 | | 16.38 | 2.367 | 16.55 | 2.307 | 15.16 | 2.094 | 13.79 |
| | | +29 | | —12 | +13 | —13 | +15 | —5 | +27 | +5 |
| (*6*) | 0 | 5 | 0 | 0 | 900 | 14.94 | 2.510 | 17.8 | 0.80 | 4.50 |
| | | 1.645 | | 13.76 | 1.858 | 13.88 | 1.764 | 12.18 | 1.636 | 11.42 |
| | | +53 | | +9 | +35 | +8 | +43 | +23 | +53 | +31 |
| (*7*) | 0 | 5 | 0 | 0 | 1076 | 23.57 | 4.150 | 35.2 | 1.56 | 4.43 |
| | | 2.760 | | 21.62 | 3.182 | 21.86 | 3.070 | 19.51 | 2.819 | 18.02 |
| | | +50 | | +9 | +30 | +8 | +35 | +21 | +47 | +31 |
| (*8*) | 0 | 5 | 0 | 0 | 984 | 14.97 | 2.802 | 25.2 | 1.08 | 4.29 |
| | | 2.087 | | 16.82 | 2.377 | 17.00 | 2.279 | 14.94 | 2.099 | 13.94 |
| | | +34 | | —11 | +18 | —12 | +23 | 0 | +33 | +7 |
| (*9*) | 0 | 7 | 0 | 0 | 782 | 13.90 | 2.473 | 20.5 | 1.16 | 5.66 |
| | | 1.890 | | 15.18 | 2.168 | 15.30 | 2.123 | 14.48 | 1.917 | 12.81 |
| | | +31 | | —8 | +14 | —9 | +16 | —4 | +29 | +9 |
| (*10*) | 4 | 9 | 0 | 0 | 1034 | 16.74 | 2.696 | 18.6 | 0.97 | 5.22 |
| | | 1.877 | | 15.84 | 2.119 | 15.97 | 2.032 | 14.32 | 1.867 | 13.27 |
| | | +43 | | +6 | +27 | +5 | +33 | +17 | +44 | +26 |
| (*11*) | 0 | 2 | 0 | 0 | 1020 | 19.18 | 3.303 | 25.9 | 1.24 | 4.79 |
| | | 2.229 | | 18.06 | 2.553 | 18.24 | 2.456 | 16.26 | 2.255 | 15.08 |
| | | +48 | | +6 | +29 | +5 | +35 | +18 | +47 | +27 |
| (*12*) | 0 | 5 | 0 | 0 | 868 | 18.17 | 2.897 | 25.5 | 1.18 | 4.63 |
| | | 2.099 | | 16.70 | 2.418 | 16.88 | 2.338 | 15.12 | 2.139 | 13.97 |
| | | +38 | | +9 | +20 | +8 | +24 | +20 | +35 | +30 |
| (*13*) | 0 | 4 | 0 | 0 | 914 | 15.99 | 2.935 | 25.7 | 1.27 | 4.94 |
| | | 2.182 | | 17.48 | 2.516 | 17.66 | 2.439 | 15.92 | 2.225 | 14.66 |
| | | +34 | | —9 | +16 | —9 | +20 | 0 | +32 | +9 |
| (*14*) | 0 | 3 | 0 | 0 | 869 | 17.12 | 3.000 | 24.7 | 1.16 | 4.71 |
| | | 2.053 | | 16.40 | 2.362 | 16.57 | 2.280 | 14.83 | 2.090 | 13.72 |
| | | +46 | | +4 | +27 | +3 | +32 | +15 | +44 | +25 |
| (*15*) | 0 | 2 | 0 | 0 | 836 | 13.01 | 2.400 | 23.1 | 0.95 | 4.11 |
| | | 1.833 | | 14.55 | 2.087 | 14.71 | 2.009 | 12.90 | 1.844 | 12.03 |
| | | +31 | | —11 | +15 | —12 | +19 | +1 | +30 | +8 |
| (*16*) | 0 | 4 | 0 | 0 | 916 | 18.63 | 3.185 | 31.2 | 1.50 | 4.81 |
| | | 2.466 | | 19.28 | 2.856 | 19.49 | 2.772 | 17.56 | 2.531 | 16.14 |
| | | +29 | | —3 | +12 | —4 | +15 | +6 | +26 | +15 |
| (*17*) | 0 | 7 | 0 | 0 | 944 | 14.28 | 2.491 | 20.8 | 0.96 | 4.62 |
| | | 1.846 | | 15.22 | 2.096 | 15.37 | 1.998 | 13.53 | 1.845 | 12.66 |
| | | +35 | | —6 | +19 | —7 | +25 | +6 | +35 | +13 |
| (*18*) | 0 | 2 | 0 | 0 | 948 | 16.80 | 3.000 | 23.5 | 1.18 | 5.02 |
| | | 2.074 | | 16.87 | 2.379 | 17.04 | 2.297 | 15.28 | 2.102 | 14.14 |
| | | +45 | | 0 | +26 | —1 | +31 | +10 | +43 | +19 |
| (*19*) | 0 | 4 | 0 | 0 | 942 | 18.86 | 3.220 | 25.6 | 1.26 | 4.92 |
| | | 2.195 | | 17.66 | 2.528 | 17.84 | 2.448 | 16.06 | 2.237 | 14.81 |
| | | +46 | | +7 | +27 | +6 | +32 | +17 | +43 | +27 |
| (*20*) | 0 | 5 | 0 | 0 | 765 | 15.26 | 2.463 | 19.4 | 0.98 | 5.04 |
| | | 1.700 | | 13.79 | 1.952 | 13.92 | 1.886 | 12.50 | 1.725 | 11.56 |
| | | +45 | | +11 | +26 | +10 | +31 | +22 | +43 | +32 |
| (*21*) | 2 | 7 | 0 | 0 | 779 | 12.24 | 2.275 | 16.2 | 0.98 | 6.14 |
| | | 1.671 | | 13.73 | 1.890 | 13.81 | 1.860 | 13.36 | 1.668 | 11.65 |
| | | +36 | | —11 | +20 | —11 | +22 | —8 | +36 | +5 |
| (*22*) | 0 | 4 | 0 | 0 | 935 | 18.80 | 3.135 | 18.5 | 0.83 | 4.49 |
| | | 1.709 | | 14.30 | 1.931 | 14.43 | 1.832 | 12.65 | 1.700 | 11.87 |
| | | +83 | | +31 | +62 | +30 | +71 | +49 | +84 | +58 |
| (*23*) | 0 | 3 | 0 | 0 | 905 | 18.15 | 2.945 | 28.0 | 1.38 | 4.93 |
| | | 2.314 | | 18.32 | 2.678 | 18.52 | 2.604 | 16.74 | 2.372 | 15.38 |
| | | +27 | | —1 | +10 | —2 | +13 | +8 | +24 | +18 |
| (*24*) | 0 | 6 | 0 | 0 | 914 | 13.92 | 2.419 | 15.1 | 0.74 | 4.90 |
| | | 1.546 | | 13.26 | 1.742 | 13.36 | 1.658 | 11.79 | 1.532 | 11.06 |
| | | +56 | | +5 | +39 | +4 | +46 | +18 | +58 | +26 |
| (*25*) | 0 | 5 | 0 | 0 | 779 | 14.72 | 2.530 | 22.7 | 1.23 | 5.42 |
| | | 1.998 | | 15.80 | 2.293 | 15.96 | 2.247 | 14.86 | 2.031 | 13.34 |
| | | +27 | | —7 | +10 | —8 | +13 | —1 | +25 | +10 |
| (*26*) | 0 | 7 | 0 | 0 | 854 | 12.80 | 2.140 | 16.4 | 0.78 | 4.70 |
| | | 1.557 | | 13.07 | 1.762 | 13.20 | 1.775 | 12.08 | 1.649 | 11.34 |
| | | +37 | | —2 | +22 | —3 | +21 | +6 | +30 | +13 |

TABLE F.—HIGH PROTEIN: 26 CLASS B RECORDS, AVERAGE LENGTH 165 DAYS

(*1*) Cloedah, '07, J, 5, 217. (*2*) Electa, '09, J, 4, 189. (*3*) Madam, '05, J, 4, 182. (*4*) Madam, '05, J, 5, 210. (*5*) Peggy, '05, J, 4, 210. (*6*) Phoebe, '09, H, 4, 126. (7) Phoebe, '09, H, 5, 161. (*8*) Rosel, '96, J, '11, 210. (*9*) Vt. Peony, '08, *J*, 5, 217. (*10*) Zeta, '99, J, 9, 210. (*11*) Zeta, '99, J, 10, 210. (*12*) Alta, '97, J, 11, 189. (*13*) Avis, '00, J, 8, 161. (*14*) Avis, '00, J, 13, 217. (*15*) Dewdrop, '00, J, 7, 175. (*16*) Dewdrop, '00, J, 9, 112. (*17*) Doris, '01, J, 6, 175. (*18*) Hester, '01, J, 6, 175. (*19*) Kate, '00, J, 9, 140. (*20*) Kate, '00, J, 11, 126. (*21*) Lena, '03, J, 5, 126. (*22*) Mildred, '03, J, 9, 217. (*23*) Monetta, '06, *J*, 6, 196. (*24*) Santa Rosa, '99, J, 8, 126. (*25*) Santa Rosa, '99, J, 12, 119. (*26*) Tansy, '03, J, 5, 112.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 2 | 9 | 0 | 3 | 938 | 12.40 | 1.765 | 10.0 | 0.59 | 5.90 |
| | | | 1.327 | 11.95 | 1.467 | 12.01 | 1.391 | 10.94 | 1.283 | 9.98 |
| | | | +33 | +4 | +20 | +3 | +27 | +13 | +38 | +24 |
| (*2*) | 0 | 6 | 0 | 1 | 814 | 14.63 | 2.657 | 21.6 | 1.23 | 5.69 |
| | | | 1.985 | 15.92 | 2.276 | 16.05 | 2.232 | 15.20 | 2.014 | 13.44 |
| | | | +34 | —8 | +17 | —9 | +19 | —4 | +32 | +9 |
| (*3*) | 0 | 6 | 0 | 4 | 862 | 14.62 | 2.566 | 12.5 | 0.69 | 5.52 |
| | | | 1.403 | 12.14 | 1.566 | 12.22 | 1.495 | 10.98 | 1.376 | 10.15 |
| | | | +83 | +21 | +64 | +20 | +71 | +33 | +87 | +44 |
| (*4*) | 0 | 7 | 0 | 4 | 914 | 12.85 | 2.220 | 12.7 | 0.66 | 5.20 |
| | | | 1.427 | 12.47 | 1.592 | 12.56 | 1.511 | 11.13 | 1.387 | 10.41 |
| | | | +56 | +3 | +39 | +2 | +47 | +15 | +59 | +23 |
| (*5*) | 2 | 9 | 0 | 4 | 840 | 18.18 | 3.220 | 22.3 | 1.34 | 6.01 |
| | | | 2.082 | 16.72 | 2.394 | 16.85 | 2.356 | 16.28 | 2.118 | 14.13 |
| | | | +55 | +9 | +35 | +8 | +37 | +12 | +52 | +29 |
| (*6*) | 0 | 4 | 0 | 2 | 1013 | 16.86 | 2.820 | 33.7 | 1.21 | 3.59 |
| | | | 2.360 | 18.58 | 2.764 | 18.78 | 2.688 | 16.75 | 2.406 | 15.22 |
| | | | +19 | —9 | +2 | —10 | +5 | +1 | +17 | +11 |
| (7) | 0 | 5 | 0 | 2 | 1003 | 16.21 | 2.876 | 29.0 | 0.99 | 3.42 |
| | | | 2.123 | 17.03 | 2.471 | 17.20 | 2.391 | 15.27 | 2.150 | 13.95 |
| | | | +35 | —5 | +16 | —6 | +20 | +6 | +34 | +16 |
| (*8*) | 3 | 10 | 0 | 2 | 1035 | 19.76 | 3.158 | 23.5 | 1.14 | 4.85 |
| | | | 2.099 | 17.26 | 2.393 | 17.42 | 2.294 | 15.46 | 2.112 | 14.40 |
| | | | +50 | +15 | +32 | +14 | +38 | +28 | +50 | +37 |
| (*9*) | 0 | 7 | 0 | 2 | 806 | 13.17 | 2.207 | 16.3 | 0.95 | 5.83 |
| | | | 1.632 | 13.53 | 1.852 | 13.63 | 1.799 | 12.70 | 1.634 | 11.38 |
| | | | +35 | —3 | +19 | —4 | +23 | +4 | +35 | +16 |
| (*10*) | 1 | 8 | 0 | 5 | 865 | 17.34 | 2.680 | 18.9 | 0.94 | 4.97 |
| | | | 1.740 | 14.38 | 1.985 | 14.51 | 1.909 | 12.95 | 1.752 | 12.04 |
| | | | +54 | +21 | +35 | +20 | +40 | +34 | +53 | +44 |
| (*11*) | 1 | 8 | 0 | 2 | 867 | 20.00 | 3.115 | 19.5 | 0.95 | 4.87 |
| | | | 1.748 | 14.38 | 1.991 | 14.52 | 1.908 | 12.89 | 1.758 | 12.00 |
| | | | +78 | +39 | +56 | +38 | +63 | +55 | +77 | +67 |
| (*12*) | 0 | 6 | 0 | 1 | 848 | 15.98 | 2.450 | 20.7 | 1.03 | 4.98 |
| | | | 1.836 | 14.96 | 2.105 | 15.01 | 2.031 | 13.54 | 1.859 | 12.54 |
| | | | +33 | +7 | +16 | +6 | +20 | +18 | +32 | +27 |
| (*13*) | 0 | 5 | 0 | 3 | 803 | 16.28 | 2.808 | 24.8 | 1.14 | 4.60 |
| | | | 1.976 | 15.59 | 2.273 | 15.77 | 2.190 | 14.04 | 2.010 | 13.00 |
| | | | +42 | +4 | +24 | +3 | +28 | +16 | +40 | +25 |
| (*14*) | 2 | 9 | 0 | 3 | 854 | 11.98 | 1.913 | 11.7 | 0.56 | 4.79 |
| | | | 1.282 | 11.28 | 1.429 | 11.36 | 1.343 | 9.89 | 1.253 | 9.36 |
| | | | +49 | +6 | +34 | +5 | +43 | +21 | +53 | +28 |
| (*15*) | 0 | 5 | 0 | 4 | 810 | 15.99 | 2.590 | 21.6 | 1.16 | 5.37 |
| | | | 1.906 | 15.30 | 2.187 | 15.45 | 2.126 | 14.11 | 1.934 | 12.88 |
| | | | +36 | +5 | +18 | +3 | +22 | +13 | +34 | +24 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*16*) | 0 | 4 | 0 | 1 | 877 | 18.40 | 3.010 | 23.2 | 1.25 | 5.39 |
| | | | 2.099 | 16.79 | 2.400 | 16.95 | 2.342 | 15.70 | 2.122 | 14.15 |
| | | | +43 | +10 | +25 | +9 | +29 | +17 | +42 | +28 |
| (*17*) | 0 | 5 | 0 | 1 | 795 | 13.91 | 2.323 | 15.5 | 0.80 | 5.16 |
| | | | 1.518 | 12.68 | 1.719 | 12.78 | 1.653 | 11.51 | 1.496 | 10.63 |
| | | | +56 | +10 | +38 | +9 | +41 | +21 | +55 | +31 |
| (*18*) | 0 | 5 | 0 | 1 | 835 | 15.02 | 2.700 | 20.2 | 0.99 | 4.90 |
| | | | 1.797 | 14.66 | 2.059 | 14.80 | 1.987 | 13.26 | 1.819 | 12.28 |
| | | | +50 | +2 | +31 | +1 | +36 | +13 | +48 | +22 |
| (*19*) | 0 | 5 | 0 | 2 | 896 | 18.55 | 3.221 | 30.9 | 1.63 | 5.28 |
| | | | 2.543 | 19.81 | 2.944 | 20.02 | 2.887 | 18.49 | 2.612 | 16.72 |
| | | | +27 | —6 | +9 | —7 | +11 | 0 | +23 | +11 |
| (*20*) | 0 | 4 | 0 | 1 | 876 | 14.01 | 2.690 | 26.0 | 1.28 | 4.95 |
| | | | 2.173 | 17.30 | 2.511 | 17.48 | 2.438 | 15.79 | 2.223 | 14.52 |
| | | | +24 | —19 | +7 | —20 | +10 | —11 | +21 | —4 |
| (*21*) | 0 | 4 | 0 | 1 | 836 | 15.65 | 2.952 | 30.4 | 1.47 | 4.84 |
| | | | 2.364 | 18.33 | 2.644 | 18.55 | 2.667 | 16.75 | 2.434 | 15.37 |
| | | | +25 | —15 | +12 | —16 | +11 | —7 | +21 | +2 |
| (*22*) | 0 | 7 | 0 | 5 | 865 | 14.30 | 2.535 | 18.9 | 0.92 | 4.87 |
| | | | 1.711 | 14.14 | 1.947 | 14.27 | 1.864 | 12.65 | 1.717 | 11.79 |
| | | | +48 | +1 | +30 | 0 | +36 | +13 | +48 | +21 |
| (*23*) | 0 | 6 | 0 | 2 | 841 | 14.11 | 2.445 | 24.6 | 1.35 | 5.50 |
| | | | 2.163 | 17.10 | 2.483 | 17.27 | 2.432 | 16.07 | 2.198 | 14.43 |
| | | | +13 | —17 | —2 | —18 | +1 | —12 | +11 | —2 |
| (*24*) | 0 | 4 | 0 | 1 | 904 | 16.15 | 2.746 | 23.5 | 1.09 | 4.64 |
| | | | 1.972 | 15.91 | 2.254 | 16.08 | 2.158 | 14.23 | 1.992 | 13.24 |
| | | | +39 | +2 | +22 | 0 | +27 | +13 | +38 | +22 |
| (*25*) | 0 | 4 | 0 | 2 | 941 | 15.27 | 2.731 | 17.4 | 0.78 | 4.48 |
| | | | 1.651 | 13.94 | 1.859 | 14.06 | 1.760 | 12.30 | 1.637 | 11.57 |
| | | | +65 | +10 | +47 | +9 | +55 | +24 | +67 | +32 |
| (*26*) | 0 | 4 | 0 | 1 | 867 | 17.10 | 2.963 | 28.0 | 1.39 | 4.98 |
| | | | 2.287 | 18.02 | 2.651 | 18.22 | 2.582 | 16.50 | 2.349 | 15.13 |
| | | | +30 | —5 | +12 | —6 | +15 | +4 | +26 | +13 |

TABLE G.—VERY LOW PROTEIN: 6 CLASS A RECORDS, AVERAGE LENGTH 145 DAYS

(*1*) Cherry. '00, J, 15, 210. (*2*) Granny, '10, J. 6, 210. (*3*) Janet, '10, J, 5, 119. (*4*) Phoebe, '09, H, 7, 140. (*5*) Vic, '10, J, 5, 98. (*6*) Vic, '10, J, 6, 91.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 0 | 7 | 0 | 0 | *880* | 13.41 | 1.115 | 15.1 | 0.66 | 4.37 |
| | | | 1.454 | 12.38 | 1.628 | 12.49 | 1.539 | 10.84 | 1.431 | 10.24 |
| | | | —23 | +8 | —32 | +8 | —28 | +24 | —22 | +31 |
| (*2*) | 1 | 8 | 0 | 0 | *900* | 14.07 | 1.100 | 17.9 | 0.96 | 5.36 |
| | | | 1.740 | 14.49 | 1.973 | 14.62 | 1.898 | 13.17 | 1.738 | 12.16 |
| | | | —37 | —3 | —44 | —4 | —42 | +7 | —37 | +16 |
| (*3*) | 0 | 3 | 0 | 0 | *820* | 15.52 | 1.328 | 22.8 | 1.22 | 5.36 |
| | | | 1.988 | 15.87 | 2.284 | 16.03 | 2.224 | 14.67 | 2.021 | 13.37 |
| | | | —33 | —2 | —42 | —3 | —40 | +6 | —34 | +16 |
| (*4*) | 0 | 4 | 0 | 0 | *960* | 16.22 | 1.235 | 33.7 | 1.24 | 3.68 |
| | | | 2.408 | 18.67 | 2.795 | 18.90 | 2.716 | 16.77 | 2.455 | 15.39 |
| | | | —49 | —13 | —56 | —14 | —55 | —3 | —50 | +5 |
| (*5*) | 0 | 3 | 0 | 0 | *800* | 16.02 | 1.367 | 27.0 | 1.45 | 5.37 |
| | | | 2.234 | 17.44 | 2.585 | 17.63 | 2.531 | 16.26 | 2.291 | 14.71 |
| | | | —39 | —8 | —47 | —9 | —46 | —1 | —40 | +9 |
| (*6*) | 0 | 2 | 0 | 0 | *770* | 15.92 | 1.187 | 26.0 | 1.46 | 5.62 |
| | | | 2.203 | 17.13 | 2.541 | 17.31 | 2.500 | 16.22 | 2.253 | 14.48 |
| | | | —46 | —7 | —53 | —8 | —53 | —2 | —47 | +10 |

### TABLE H.—VERY LOW PROTEIN: 9 CLASS B RECORDS, AVERAGE LENGTH 168 DAYS

(*1*) Alice, '11, J, 4, 119. (*2*) Catrina 2nd, '04, HJ, 10, 161. (*3*) Katydid, '09, J, 5, 196. (*4*) Katydid, '09, J, 7, 168. (*5*) Phoebe, '09, H, 6, 161. (*6*) Theta, '08, J, 7, 140. (*7*) Vt. Peony, '08, *J*, 9, 210. (*8*) Granny, '10, J, 4, 210. (*9*) Vt. Una 2nd, '11, *J*, 5, 161.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 0 | 4 | 0 | 1 | *830* | 14.19 | 1.210 | 19.5 | 1.05 | 5.38 |
| | | | 1.829 | 14.85 | 2.083 | 14.99 | 2.026 | 13.80 | 1.840 | 12.50 |
| | | | —34 | —4 | —42 | —5 | —40 | +3 | —34 | +14 |
| (*2*) | 0 | 5 | 0 | 2 | *890* | 16.01 | 1.430 | 27.9 | 1.19 | 4.27 |
| | | | 2.172 | 17.05 | 2.492 | 17.24 | 2.404 | 15.26 | 2.207 | 14.14 |
| | | | —34 | —6 | —43 | —7 | —40 | +5 | —35 | +13 |
| (*3*) | 1 | 7 | 0 | 4 | *800* | 14.70 | 1.265 | 23.7 | 1.26 | 5.32 |
| | | | 2.029 | 16.08 | 2.338 | 16.25 | 2.280 | 14.91 | 2.070 | 13.55 |
| | | | —38 | —9 | —46 | —10 | —45 | —1 | —39 | +8 |
| (*4*) | 0 | 5 | 0 | 3 | *750* | 15.33 | 1.202 | 22.7 | 1.25 | 5.50 |
| | | | 1.978 | 15.57 | 2.273 | 15.73 | 2.228 | 14.67 | 2.014 | 13.15 |
| | | | —41 | —2 | —47 | —3 | —46 | +4 | —40 | +17 |
| (*5*) | 0 | 5 | 0 | 1 | *1000* | 16.19 | 1.391 | 29.7 | 1.03 | 3.47 |
| | | | 2.155 | 17.22 | 2.512 | 17.40 | 2.432 | 15.46 | 2.185 | 14.12 |
| | | | —35 | —6 | —45 | —7 | —43 | +5 | —36 | +15 |
| (*6*) | 0 | 4 | 0 | 1 | *760* | 15.18 | 1.314 | 24.1 | 1.29 | 5.35 |
| | | | 2.026 | 15.93 | 2.340 | 16.10 | 2.288 | 14.81 | 2.072 | 13.44 |
| | | | —35 | —5 | —44 | —6 | —43 | +3 | —37 | +13 |
| (*7*) | 2 | 9 | 0 | 5 | *780* | 11.77 | 0.857 | 9.3 | 0.53 | 5.70 |
| | | | 1.141 | 10.13 | 1.262 | 10.19 | 1.194 | 9.07 | 1.106 | 8.45 |
| | | | —25 | +16 | —32 | +15 | —28 | +30 | —22 | +39 |
| (*8*) | 2 | 9 | 0 | 5 | *960* | 13.90 | 1.166 | 14.6 | 0.82 | 5.62 |
| | | | 1.606 | 13.80 | 1.796 | 13.91 | 1.718 | 12.52 | 1.579 | 11.55 |
| | | | —27 | +1 | —35 | 0 | —32 | +11 | —26 | +20 |
| (*9*) | 0 | 5 | 0 | 3 | *730* | 13.92 | 1.043 | 16.9 | 0.93 | 5.52 |
| | | | 1.593 | 12.95 | 1.812 | 13.07 | 1.761 | 12.03 | 1.601 | 10.90 |
| | | | —35 | +7 | —42 | +7 | —41 | +16 | —35 | +28 |

### TABLE I.—LOW PROTEIN: 24 CLASS C RECORDS, AVERAGE LENGTH 177 DAYS

(*1*) Ardelle, '03, J, 4, 175. (*2*) Ardelle, '03, J, 5, 210. (*3*) Ardelle, '03, J, 11, 189. (*4*) Fyra, ?, H, 12, 224. (*5*) Grace, '02, J, 11, 119. (*6*) Grace, '02, J, 12, 210. (*7*) Sheila, '02, J, 7, 140. (*8*) Cherry, '00, J, 9, 189. (*9*) Edith, '98, J, 12, 210. (*10*) Laura B., '07, J, 6, 119. (*11*) Lena, '03, J, 6, 210. (*12*) Vie, '02, J, 9, 217. (*13*) Zillah, '02, *A*, 5, 49. (*14*) Zillah, '02, *A*, 7, 119. (*15*) Zillah, '02, *A*, 9, 217. (*16*) Zillah, '02, *A*, 11, 224. (*17*) Ardelle, '03, J, 11, 140. (*18*) Grace, '02, J, 13, 210. (*19*) Kinky, '10, J, 5, 210. (*20*) Laura B, '07, J, 8, 140. (*21*) Sheila, '02, J, 12, 105. (*22*) Vt. Aster, '05, *J*, 3, 210. (*23*) Fyra, ?, H, 8, 210. (*24*) Fyra, ?, H, 10, 210.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 5 | 10 | 2 | 7 | 667 | 11.50 | 1.166 | 11.5 | 0.70 | 6.09 |
| | | | 1.237 | 10.48 | 1.398 | 10.54 | 1.355 | 9.92 | 1.231 | 8.81 |
| | | | —6 | +10 | —17 | +9 | —14 | +16 | —5 | +31 |
| (*2*) | 2 | 9 | 0 | 7 | 738 | 12.89 | 1.234 | 12.4 | 0.74 | 5.97 |
| | | | 1.347 | 11.44 | 1.521 | 11.52 | 14.72 | 10.81 | 1.339 | 9.62 |
| | | | —8 | +13 | —19 | +12 | —16 | +19 | —8 | +34 |
| (*3*) | 4 | 10 | 1 | 7 | 817 | 11.27 | 1.132 | 10.8 | 0.64 | 5.93 |
| | | | 1.296 | 11.35 | 1.447 | 11.41 | 1.386 | 10.54 | 1.270 | 9.50 |
| | | | —13 | —1 | —22 | —1 | —18 | +7 | —11 | +19 |
| (*4*) | 4 | 11 | 1 | 8 | 1117 | 14.20 | 1.482 | 19.9 | 0.85 | 4.27 |
| | | | 1.886 | 15.98 | 2.115 | 16.12 | 2.001 | 14.00 | 1.859 | 13.21 |
| | | | —21 | —11 | —30 | —12 | —26 | +1 | —20 | +7 |
| (*5*) | 4 | 8 | 1 | 5 | 963 | 12.50 | 1.185 | 10.8 | 0.54 | 5.00 |
| | | | 1.322 | 11.94 | 1.463 | 12.01 | 1.370 | 10.44 | 1.280 | 9.91 |
| | | | —10 | +5 | —19 | +4 | —13 | +20 | —7 | +26 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*6*) | 4 | 11 | 0 | 6 | 917 | 11.67 | 1.200 | 10.7 | 0.57 | 5.33 |
| | | | 1.305 | 11.67 | 1.444 | 11.74 | 1.360 | 10.33 | 1.265 | 9.72 |
| | | | —8 | 0 | —17 | —1 | —12 | +13 | —5 | +20 |
| (*7*) | 5 | 11 | 0 | 6 | 842 | 16.49 | 1.514 | 10.6 | 0.62 | 5.85 |
| | | | 1.284 | 11.32 | 1.427 | 11.38 | 1.359 | 10.32 | 1.252 | 9.47 |
| | | | +18 | +46 | +6 | +45 | +11 | +60 | +21 | +74 |
| (*8*) | 4 | 10 | 0 | 4 | 951 | 15.38 | 1.651 | 13.0 | 0.65 | 5.02 |
| | | | 1.446 | 12.72 | 1.615 | 12.81 | 1.525 | 11.22 | 1.417 | 10.59 |
| | | | +14 | +21 | +2 | +20 | +8 | +37 | +16 | +45 |
| (*9*) | 8 | 15 | 0 | 3 | 947 | 14.19 | 1.524 | 13.4 | 0.71 | 5.30 |
| | | | 1.494 | 13.02 | 1.668 | 13.11 | 1.584 | 11.64 | 1.465 | 10.87 |
| | | | +2 | +9 | —9 | +8 | —4 | +21 | +4 | +31 |
| (*10*) | 7 | 11 | 4 | 8 | 875 | 12.81 | 1.337 | 12.3 | 0.78 | 6.34 |
| | | | 1.467 | 12.67 | 1.633 | 12.73 | 1.581 | 11.97 | 1.435 | 10.63 |
| | | | —9 | +1 | —18 | +1 | —15 | +7 | —7 | +20 |
| (*11*) | 9 | 16 | 0 | 7 | 888 | 12.35 | 1.305 | 10.9 | 0.58 | 5.33 |
| | | | 1.297 | 11.52 | 1.439 | 11.60 | 1.359 | 10.23 | 1.261 | 9.60 |
| | | | +1 | +7 | —9 | +7 | —4 | +21 | +4 | +29 |
| (*12*) | 3 | 10 | 0 | 7 | 1018 | 13.03 | 1.410 | 14.0 | 0.55 | 3.96 |
| | | | 1.469 | 12.87 | 1.623 | 12.97 | 1.522 | 11.14 | 1.422 | 10.61 |
| | | | —4 | +1 | —13 | 0 | —7 | +17 | —1 | +23 |
| (*13*) | 8 | 10 | 5 | 7 | 983 | 15.50 | 1.204 | 10.8 | 0.49 | 4.54 |
| | | | 1.304 | 11.81 | 1.433 | 11.89 | 1.330 | 10.21 | 1.253 | 9.76 |
| | | | —8 | +31 | —16 | +30 | —10 | +52 | —4 | +59 |
| (*14*) | 9 | 13 | 3 | 7 | 999 | 13.32 | 1.370 | 11.6 | 0.47 | 4.06 |
| | | | 1.326 | 11.90 | 1.453 | 11.98 | 1.353 | 10.23 | 1.271 | 9.80 |
| | | | +3 | +12 | —6 | +11 | +1 | +30 | +8 | +36 |
| (*15*) | 6 | 13 | 0 | 7 | 992 | 13.46 | 1.442 | 13.0 | 0.46 | 3.56 |
| | | | 1.331 | 11.94 | 1.487 | 12.01 | 1.394 | 10.36 | 1.286 | 9.77 |
| | | | +8 | +13 | —3 | +12 | +3 | +29 | +12 | +38 |
| (*16*) | 2 | 9 | 0 | 7 | 1012 | 12.74 | 1.308 | 15.7 | 0.64 | 4.08 |
| | | | 1.556 | 13.41 | 1.729 | 13.52 | 1.630 | 11.65 | 1.517 | 11.05 |
| | | | —16 | —5 | —24 | —6 | —20 | +9 | —14 | +15 |
| (*17*) | 4 | 10 | 2 | 8 | *810* | 13.40 | 1.350 | 12.6 | 0.76 | 6.03 |
| | | | 1.411 | 12.11 | 1.588 | 12.18 | 1.532 | 11.38 | 1.397 | 10.16 |
| | | | —4 | +11 | —15 | +10 | —12 | +18 | —3 | +32 |
| (*18*) | 2 | 9 | 6 | 13 | *900* | 13.46 | 1.343 | 14.3 | 0.74 | 5.18 |
| | | | 1.517 | 13.01 | 1.703 | 13.11 | 1.625 | 11.70 | 1.497 | 10.88 |
| | | | —11 | +3 | —21 | +3 | —17 | +15 | —10 | +24 |
| (*19*) | 7 | 14 | 0 | 7 | *840* | 13.59 | 1.376 | 14.1 | 0.87 | 6.17 |
| | | | 1.568 | 13.23 | 1.758 | 13.30 | 1.716 | 12.68 | 1.548 | 11.13 |
| | | | —12 | +3 | —22 | +2 | —20 | +7 | —11 | +22 |
| (*20*) | 5 | 10 | 0 | 5 | *870* | 14.66 | 1.521 | 20.0 | 1.14 | 5.70 |
| | | | 1.919 | 15.66 | 2.169 | 15.78 | 2.136 | 14.82 | 1.934 | 13.20 |
| | | | —21 | —6 | —31 | —7 | —29 | —2 | —21 | +11 |
| (*21*) | 7 | 10 | 4 | 7 | 837 | 10.28 | 1.086 | 11.9 | 0.72 | 6.05 |
| | | | 1.383 | 12.00 | 1.550 | 12.08 | 1.489 | 11.20 | 1.362 | 10.06 |
| | | | —21 | —14 | —30 | —15 | —27 | —8 | —20 | +2 |
| (*22*) | 4 | 11 | 0 | 7 | 734 | 14.09 | 1.335 | 10.4 | 0.65 | 6.25 |
| | | | 1.237 | 10.67 | 1.377 | 10.72 | 1.334 | 10.09 | 1.211 | 8.95 |
| | | | +8 | +32 | —3 | +31 | 0 | +40 | +10 | +59 |
| (*23*) | 6 | 13 | 1 | 7 | 1110 | 18.20 | 1.948 | 24.1 | 1.08 | 4.48 |
| | | | 2.151 | 17.77 | 2.441 | 18.04 | 2.324 | 15.79 | 2.152 | 14.77 |
| | | | —9 | +2 | —20 | +1 | —16 | +15 | —9 | +23 |
| (*24*) | 2 | 9 | 0 | 6 | 1122 | 16.00 | 1.725 | 26.0 | 1.02 | 3.93 |
| | | | 2.189 | 17.81 | 2.475 | 18.00 | 2.370 | 15.69 | 2.183 | 14.71 |
| | | | —21 | —10 | —30 | —11 | —27 | +2 | —21 | +9 |

TABLE K.—LOW PROTEIN: 19 CLASS D RECORDS, AVERAGE LENGTH 110 DAYS

(*1*) Ardelle, '03, J, 10, 175. (*2*) Vt. Aster, '05, *J*, 7, 70. (*3*) Grace, '02, J, 5, 84. (*4*) Grace, '02, J, 6, 105. (*5*) Grace, '02, J, 9, 175. (*6*) Sheila, '02, J, 6, 70. (7) Sheila, '02, J, 9, 63. (*8*) Sheila, '02, J, 10, 70. (*9*) Sheila, '02, J, 11, 84. (*10*) Alta, '97, J, 5, 189. (*11*) Dewdrop, '00, J, 8, 84. (*12*) Elizabeth, '00, J, 13, 105. (*13*) Vie, '02, J, 5, 70. (*14*) Dot, '09, J, 6, 210. (*15*) Kinky, '10, J, 4, 49. (*16*) Monetta, '06, *J*, 8, 49. (*17*) Vt. Aster, '05, *J*, 2, 140. (*18*) Ardelle, '03, J, 12, 84. (*19*) Ardelle, '03, J, 14, 217.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 10 | 16 | 2 | 8 | 860 | 11.22 | 1.023 | 7.5 | 0.47 | 6.27 |
| | | | 1.123 | 10.32 | 1.225 | 10.35 | 1.158 | 9.43 | 1.069 | 8.59 |
| | | —9 | | +9 | —16 | +8 | —12 | +19 | —4 | +31 |
| (*2*) | 9 | 12 | 0 | 1 | 968 | 10.50 | 0.900 | 6.2 | 0.33 | 5.33 |
| | | | 1.062 | 10.22 | 1.143 | 10.27 | 1.048 | 8.82 | 0.993 | 8.46 |
| | | —15 | | +3 | —21 | +2 | —14 | +19 | —9 | +24 |
| (*3*) | 7 | 9 | 5 | 7 | 866 | 13.56 | 1.297 | 9.0 | 0.49 | 5.44 |
| | | | 1.119 | 10.22 | 1.227 | 10.28 | 1.136 | 8.82 | 1.072 | 8.44 |
| | | +16 | | +33 | +6 | +32 | +14 | +54 | +21 | +61 |
| (*4*) | 6 | 10 | 1 | 5 | 932 | 12.98 | 0.990 | 7.8 | 0.41 | 5.26 |
| | | | 1.136 | 10.60 | 1.237 | 10.65 | 1.149 | 9.24 | 1.079 | 8.79 |
| | | —13 | | +22 | —20 | +22 | —14 | +40 | —8 | +48 |
| (*5*) | 3 | 9 | 0 | 6 | 976 | 13.67 | 1.360 | 8.5 | 0.40 | 4.71 |
| | | | 1.180 | 11.01 | 1.287 | 11.07 | 1.188 | 9.49 | 1.121 | 9.11 |
| | | +16 | | +24 | +6 | +23 | +15 | +44 | +21 | +50 |
| (*6*) | 8 | 11 | 2 | 5 | 823 | 12.66 | 1.057 | 7.5 | 0.40 | 5.33 |
| | | | 1.041 | 9.61 | 1.139 | 9.66 | 1.061 | 8.41 | 0.994 | 7.99 |
| | | +2 | | +32 | —7 | +31 | 0 | +51 | +6 | +58 |
| (7) | 15 | 17 | 6 | 8 | 906 | 14.28 | 1.397 | 7.7 | 0.49 | 6.37 |
| | | | 1.169 | 10.77 | 1.273 | 10.81 | 1.203 | 9.82 | 1.111 | 8.97 |
| | | +20 | | +33 | +10 | +32 | +16 | +45 | +26 | +59 |
| (*8*) | 6 | 8 | 5 | 7 | 853 | 13.50 | 1.357 | 9.8 | 0.54 | 5.60 |
| | | | 1.224 | 10.92 | 1.352 | 10.99 | 1.277 | 9.76 | 1.184 | 9.10 |
| | | +11 | | +24 | 0 | +23 | +6 | +38 | +15 | +48 |
| (*9*) | 7 | 10 | 4 | 7 | 887 | 11.68 | 1.036 | 9.0 | 0.50 | 5.55 |
| | | | 1.197 | 10.85 | 1.310 | 10.91 | 1.235 | 9.64 | 1.149 | 9.03 |
| | | —13 | | +8 | —21 | +7 | —16 | +21 | —10 | +29 |
| (*10*) | 8 | 14 | 1 | 7 | 948 | 12.57 | 1.392 | 9.6 | 0.56 | 5.80 |
| | | | 1.292 | 11.72 | 1.422 | 11.78 | 1.341 | 10.55 | 1.243 | 9.77 |
| | | +8 | | +7 | —2 | +7 | +4 | +19 | +12 | +29 |
| (*11*) | 12 | 15 | 6 | 9 | 866 | 13.45 | 1.214 | 9.4 | 0.68 | 7.24 |
| | | | 1.302 | 11.59 | 1.443 | 11.64 | 1.410 | 11.20 | 1.276 | 9.75 |
| | | —7 | | +16 | —16 | +15 | —14 | +20 | —5 | +38 |
| (*12*) | 9 | 12 | 2 | 5 | 849 | 11.02 | 1.029 | 6.4 | 0.42 | 6.57 |
| | | | 1.055 | 9.81 | 1.138 | 9.83 | 1.056 | 8.96 | 0.993 | 8.17 |
| | | —2 | | +12 | —10 | +12 | —3 | +23 | +4 | +35 |
| (*13*) | 12 | 15 | 3 | 6 | 954 | 13.81 | 1.172 | 7.7 | 0.30 | 3.88 |
| | | | 1.084 | 10.21 | 1.168 | 10.26 | 1.071 | 8.67 | 1.017 | 8.38 |
| | | +8 | | +35 | 0 | +35 | +9 | +59 | +15 | +65 |
| (*14*) | 2 | 9 | 0 | 6 | *950* | 12.00 | 1.090 | 6.6 | 0.33 | 5.00 |
| | | | 1.061 | 10.16 | 1.147 | 10.21 | 1.053 | 8.72 | 0.997 | 8.41 |
| | | +2 | | +18 | —5 | +18 | +4 | +38 | +9 | +43 |
| (*15*) | 12 | 14 | 5 | 7 | *820* | 12.56 | 1.183 | 7.5 | 0.46 | 6.15 |
| | | | 1.095 | 10.00 | 1.197 | 10.04 | 1.135 | 9.16 | 1.047 | 8.33 |
| | | +8 | | +26 | —1 | +25 | +4 | +37 | +13 | +51 |
| (*16*) | 9 | 11 | 2 | 4 | *880* | 12.20 | 1.120 | 8.6 | 0.57 | 6.63 |
| | | | 1.244 | 11.20 | 1.364 | 11.24 | 1.317 | 10.58 | 1.199 | 9.39 |
| | | —10 | | +9 | —18 | +5 | —15 | +15 | —7 | +30 |
| (*17*) | 6 | 11 | 0 | 3 | 595 | 9.52 | 0.821 | 6.2 | 0.36 | 5.95 |
| | | | 0.832 | 7.51 | 0.919 | 7.55 | 0.870 | 6.87 | 0.804 | 6.27 |
| | | —1 | | +27 | —11 | +26 | —6 | +39 | +2 | +52 |
| (*18*) | 7 | 10 | 3 | 6 | *810* | 11.75 | 1.155 | 7.6 | 0.45 | 5.92 |
| | | | 1.076 | 9.85 | 1.183 | 9.90 | 1.115 | 8.93 | 1.034 | 8.21 |
| | | +7 | | +19 | —2 | +19 | +4 | +32 | +12 | +43 |
| (*19*) | 6 | 13 | 0 | 0 | *800* | 10.60 | 0.867 | 7.0 | 0.40 | 5.72 |
| | | | 1.019 | 9.41 | 1.113 | 9.45 | 1.042 | 8.40 | 0.972 | 7.83 |
| | | —15 | | +13 | —22 | +12 | —20 | +26 | —11 | +35 |

### TABLE L.—LOW PROTEIN: 6 CLASS E RECORDS, AVERAGE LENGTH 113 DAYS

(*1*) Grace, '02, J, 7, 70. (*2*) Grace, '02, J, 8, 140. (*3*) Grace,, '02, J, 10, 119. (*4*) Ladybird, '00, J, 12, 140. (*5*) Alice, '11, J, 5, 140. (*6*) Catrina 2nd, '10, HJ, 6, 70.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 7 | 9 | 0 | 2 | 913 | 11.16 | 0.957 | 3.8 | 0.20 | 5.27 |
| | | | 0.867 | 8.75 | 0.917 | 8.78 | 0.824 | 7.39 | 0.792 | 7.21 |
| | | | +10 | +28 | +4 | +27 | +16 | +51 | +21 | +55 |
| (*2*) | 6 | 11 | 0 | 5 | 982 | 12.00 | 1.265 | 4.2 | 0.19 | 4.53 |
| | | | 0.927 | 9.35 | 0.977 | 9.38 | 0.874 | 7.86 | 0.844 | 7.69 |
| | | | +36 | +28 | +29 | +28 | +45 | +53 | +50 | +56 |
| (*3*) | 3 | 7 | 1 | 5 | 984 | 13.65 | 1.454 | 5.7 | 0.24 | 4.22 |
| | | | 1.005 | 9.84 | 1.071 | 9.88 | 0.968 | 8.31 | 0.927 | 8.09 |
| | | | +45 | +39 | +36 | +38 | +50 | +64 | +57 | +69 |
| (*4*) | 9 | 15 | 2 | 8 | 992 | 11.03 | 0.950 | 5.9 | 0.31 | 5.27 |
| | | | 1.060 | 10.29 | 1.137 | 10.33 | 1.040 | 8.85 | 0.987 | 8.51 |
| | | | —10 | +7 | —16 | +7 | —9 | +25 | —4 | +30 |
| (*5*) | 9 | 14 | 3 | 8 | *830* | 10.79 | 0.857 | 5.5 | 0.33 | 6.10 |
| | | | 0.950 | 9.06 | 1.027 | 9.10 | 0.952 | 8.05 | 0.893 | 7.52 |
| | | | —10 | +19 | —17 | +19 | —10 | +34 | —4 | +44 |
| (*6*) | 10 | 13 | 5 | 8 | *960* | 10.97 | 0.871 | 5.4 | 0.31 | 5.75 |
| | | | 1.026 | 9.98 | 1.099 | 10.01 | 1.008 | 8.70 | 0.954 | 8.26 |
| | | | —15 | +10 | —21 | +10 | —14 | +26 | —9 | +33 |

### TABLE M.—LOW PROTEIN: 3 CLASS F RECORDS, AVERAGE LENGTH 210 DAYS

(*1*) Aggie, '99, J, 9, 210. (*2*) Aggie, '99, J, 11, 210. (*3*) Aggie, '99, J, 13, 210.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 9 | 18 | 10 | 17 | 942 | 14.85 | 1.361 | 10.4 | 0.53 | 5.10 |
| | | | 1.283 | 11.61 | 1.419 | 11.68 | 1.327 | 10.14 | 1.242 | 9.64 |
| | | | +6 | +28 | —4 | +27 | +3 | +47 | +10 | +54 |
| (*2*) | 12 | 19 | 0 | 6 | 924 | 14.76 | 1.467 | 11.8 | 0.61 | 5.17 |
| | | | 1.378 | 12.18 | 1.532 | 12.26 | 1.448 | 10.83 | 1.344 | 10.16 |
| | | | +7 | +21 | —4 | +20 | +1 | +36 | +9 | +45 |
| (*3*) | 14 | 21 | 0 | 7 | 924 | 13.61 | 1.457 | 10.0 | 0.53 | 5.32 |
| | | | 1.267 | 11.44 | 1.397 | 11.51 | 1.312 | 10.09 | 1.222 | 9.52 |
| | | | +15 | +19 | +4 | +18 | +11 | +35 | +19 | +43 |

### TABLE N.—MEDIUM PROTEIN: 20 CLASS C RECORDS, AVERAGE LENGTH 196 DAYS

(*1*) Avis, '00, J, 9, 175. (*2*) Doris, '01, J, 9, 189. (*3*) Laura B., '07, J. 5, 119. (*4*) Mildred, '03, J, 7. 210. (*5*) Zillah, '02, *A*, 8, 140. (*6*) Zillah, '*02*, *A*, 10, 217. (7) Laura B., '07, J, 7, 154. (*8*) Mattie, '04, J, 4, 196. (*9*) Mu, '00, J, 6, 175. (*10*) Elbaje, ?, H, 8, 210. (*11*) Elbaje, ?, H, 12, 210. (*12*) Edith, '98. J, 10, 210. (*13*) Goldfinch, '01, J, 9, 210. (*14*) Elbaje, ?, H, 9, 210. (*15*) Elbaje, ?, H, 13, 224. (*16*) Rocket, '05, J, 7, 210. (*17*) Slicker, '99, J, 10, 210. (*18*) Avis, '00, J, 11, 217. (*19*) Vt. Una, '00, *J*, 9, 210. (*20*) Mu, '00, J, 8, 210.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 9 | 15 | 1 | 7 | 816 | 11.66 | 1.686 | 10.6 | 0.61 | 5 72 |
| | | | 1.266 | 11.11 | 1.409 | 11.18 | 1.343 | 10.15 | 1.236 | 9.30 |
| | | | +33 | +5 | +20 | +4 | +25 | +15 | +36 | +25 |
| (*2*) | 6 | 12 | 0 | 6 | 987 | 13.19 | 1.761 | 11.9 | 0.64 | 5.38 |
| | | | 1.453 | 12.87 | 1.607 | 12.96 | 1.523 | 11.54 | 1.409 | 10.74 |
| | | | +21 | +2 | +10 | +2 | +16 | +14 | +25 | +23 |
| (*3*) | 7 | 11 | 4 | 8 | 880 | 13.87 | 1.798 | 14.7 | 0.94 | 6.33 |
| | | | 1.638 | 13.83 | 1.836 | 13.90 | 1.791 | 13.24 | 1.617 | 11.63 |
| | | | +10 | 0 | —2 | 0 | 0 | +5 | +11 | +19 |
| (*4*) | 7 | 14 | 0 | 5 | 900 | 14.08 | 1.610 | 10.8 | 0.58 | 5.37 |
| | | | 1.300 | 11.58 | 1.440 | 11.65 | 1.358 | 10.27 | 1.262 | 9.64 |
| | | | +24 | +22 | +12 | +21 | +18 | +37 | +28 | +46 |
| (*5*) | 8 | 13 | 3 | 8 | 1011 | 15.20 | 1.914 | 17.8 | 0.74 | 4.16 |
| | | | 1.696 | 14.39 | 1.900 | 14.51 | 1.798 | 12.61 | 1.671 | 11.90 |
| | | | +13 | +6 | +1 | +5 | +6 | +21 | +15 | +28 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *(6)* | 2 | 9 | 0 | 7 | 990 | 14.10 | 1.973 | 20.2 | 0.83 | 4.11 |
| | | | 1.784 | 14.78 | 2.006 | 14.92 | 1.911 | 12.97 | 1.767 | 12.19 |
| | | | +11 | —5 | —2 | —5 | +3 | +9 | +12 | +16 |
| *(7)* | 6 | 11 | 3 | 8 | 863 | 14.91 | 2.047 | 16.2 | 0.98 | 6.05 |
| | | | 1.716 | 14.44 | 1.942 | 14.54 | 1.885 | 13.70 | 1.712 | 12.41 |
| | | | +19 | +3 | +5 | +3 | +9 | +9 | +20 | +20 |
| *(8)* | 12 | 18 | 0 | 4 | 844 | 17.16 | 2.037 | 12.4 | 0.80 | 6.45 |
| | | | 1.484 | 12.65 | 1.645 | 12.69 | 1.608 | 12.17 | 1.447 | 10.62 |
| | | | +37 | +36 | +24 | +35 | +27 | +41 | +41 | +62 |
| *(9)* | 9 | 14 | 1 | 6 | 890 | 14.46 | 1.954 | 14.6 | 0.82 | 5.62 |
| | | | 1.557 | 13.25 | 1.747 | 13.25 | 1.676 | 12.07 | 1.537 | 11.09 |
| | | | +26 | +9 | +12 | +8 | +17 | +20 | +27 | +30 |
| *(10)* | 8 | 15 | 0 | 7 | 1275 | 18.17 | 2.245 | 20.2 | 0.88 | 4.36 |
| | | | 2.014 | 17.34 | 2.246 | 17.48 | 2.117 | 15.14 | 1.973 | 14.33 |
| | | | +11 | +5 | 0 | +4 | +6 | +20 | +14 | +27 |
| *(11)* | 10 | 17 | 0 | 6 | 1199 | 14.02 | 1.671 | 15.3 | 0.62 | 4.05 |
| | | | 1.666 | 14.75 | 1.834 | 14.86 | 1.715 | 12.73 | 1.606 | 12.14 |
| | | | 0 | —5 | —9 | —6 | —3 | +10 | +4 | +16 |
| *(12)* | 10 | 17 | 0 | 1 | 905 | 14.35 | 1.672 | 11.9 | 0.59 | 4.96 |
| | | | 1.348 | 11.91 | 1.502 | 12.00 | 1.416 | 10.49 | 1.317 | 9.91 |
| | | | +24 | +20 | +11 | +20 | +18 | +37 | +27 | +45 |
| *(13)* | 9 | 16 | 0 | 0 | 903 | 12.85 | 1.745 | 11.2 | 0.80 | 7.15 |
| | | | 1.461 | 12.78 | 1.629 | 12.85 | 1.603 | 12.50 | 1.444 | 10.79 |
| | | | +19 | +1 | +7 | 0 | +9 | +3 | +20 | +19 |
| *(14)* | 3 | 10 | 0 | 4 | 1274 | 18.77 | 2.745 | 29.3 | 1.17 | 3.99 |
| | | | 2.474 | 20.16 | 2.796 | 20.37 | 2.676 | 17.75 | 2.466 | 16.64 |
| | | | +11 | —7 | —2 | —8 | +3 | +6 | +11 | +13 |
| *(15)* | 2 | 7 | 0 | 5 | 1133 | 13.60 | 1.746 | 17.1 | 0.63 | 3.66 |
| | | | 1.674 | 14.59 | 1.870 | 14.71 | 1.763 | 12.70 | 1.631 | 11.99 |
| | | | +4 | —7 | —7 | —8 | —1 | +7 | +7 | +13 |
| *(16)* | 2 | 9 | 0 | 6 | 1117 | 15.67 | 2.105 | 17.6 | 1.02 | 5.80 |
| | | | 1.935 | 16.57 | 2.172 | 16.67 | 2.089 | 15.31 | 1.912 | 13.88 |
| | | | +9 | —6 | —3 | —6 | +1 | +2 | +10 | +13 |
| *(17)* | 2 | 9 | 0 | 6 | 935 | 16.57 | 2.228 | 17.3 | 0.91 | 5.26 |
| | | | 1.727 | 14.52 | 1.952 | 14.65 | 1.875 | 13.15 | 1.720 | 12.17 |
| | | | +29 | +14 | +14 | +13 | +19 | +26 | +29 | +36 |
| *(18)* | 4 | 11 | 0 | 6 | 847 | 12.45 | 1.828 | 12.9 | 0.67 | 5.20 |
| | | | 1.393 | 12.02 | 1.560 | 12.11 | 1.489 | 10.78 | 1.371 | 10.05 |
| | | | +31 | +4 | +17 | +3 | +23 | +16 | +33 | +24 |
| *(19)* | 3 | 10 | 0 | 7 | 918 | 14.66 | 1.962 | 12.4 | 0.71 | 5.73 |
| | | | 1.455 | 12.71 | 1.622 | 12.79 | 1.549 | 11.64 | 1.424 | 10.63 |
| | | | +35 | +15 | +21 | +14 | +27 | +25 | +38 | +38 |
| *(20)* | 2 | 9 | 0 | 6 | 858 | 15.70 | 1.995 | 17.0 | 0.87 | 5.12 |
| | | | 1.621 | 13.57 | 1.842 | 13.69 | 1.765 | 12.17 | 1.624 | 11.34 |
| | | | +23 | +16 | +8 | +15 | +13 | +29 | +23 | +38 |

### TABLE O.—MEDIUM PROTEIN: 10 CLASS D RECORDS, AVERAGE LENGTH 141 DAYS

**(*1*) Elbaje, ?, H, 7, 49. (*2*) Lizzie Hexam, '99, J, 9, 189. (*3*) Ryllis, '07, J, 6, 105. (*4*) Slicker, '99, J, 9, 154. (*5*) Edith, '98, J, 13, 217. (*6*) Ladybird, '00, J, 13, 175. (*7*) Tansy, '03, J, 5, 119. (*8*) Rena, '10, J, 4, 140. (*9*) Ryllis, '07, J, 7, 105. (*10*) Rocket, '05, J, 2, 154.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *(1)* | ? | ? | 5 | 7 | 1196 | 13.33 | 1.306 | 9.8 | 0.41 | 4.19 |
| | | | 1.383 | 12.20 | 1.495 | 12.27 | 1.371 | 11.08 | 1.301 | 10.69 |
| | | | —6 | +9 | —13 | +9 | —5 | +20 | 0 | +25 |
| *(2)* | 10 | 16 | 0 | 5 | 956 | 13.13 | 1.460 | 8.4 | 0.43 | 5.08 |
| | | | 1.173 | 10.92 | 1.282 | 10.98 | 1.189 | 9.46 | 1.118 | 9.05 |
| | | | +24 | +20 | +14 | +20 | +23 | +39 | +31 | +45 |
| *(3)* | 6 | 9 | 3 | 6 | 816 | 9.86 | 1.304 | 8.5 | 0.53 | 6.24 |
| | | | 1.162 | 10.43 | 1.277 | 10.47 | 1.219 | 9.65 | 1.118 | 8.72 |
| | | | +12 | —5 | +2 | —6 | +7 | +2 | +17 | +13 |
| *(4)* | 9 | 14 | 0 | 5 | 901 | 13.29 | 1.456 | 9.2 | 0.53 | 5.77 |
| | | | 1.233 | 11.17 | 1.358 | 11.23 | 1.281 | 10.06 | 1.188 | 9.32 |
| | | | +18 | +20 | +7 | +18 | +14 | +32 | +23 | +43 |
| *(5)* | 11 | 18 | 0 | 0 | 907 | 12.79 | 1.696 | 9.1 | 0.45 | 4.95 |
| | | | 1.181 | 10.81 | 1.299 | 10.88 | 1.211 | 9.41 | 1.135 | 8.97 |
| | | | +44 | +18 | +31 | +17 | +40 | +36 | +49 | +43 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (6) | 6 | 12 | 2 | 8 | 933 | 10.80 | 1.337 | 7.6 | 0.42 | 5.53 |
| | | | 1.140 | 10.62 | 1.238 | 10.67 | 1.152 | 9.33 | 1.080 | 8.82 |
| | | | +17 | +2 | +8 | +1 | +16 | +16 | +24 | +22 |
| (7) | 9 | 11 | 6 | 8 | 1027 | 12.98 | 1.653 | 8.0 | 0.51 | 6.38 |
| | | | 1.295 | 11.98 | 1.399 | 12.02 | 1.325 | 10.97 | 1.220 | 9.98 |
| | | | +28 | +8 | +18 | +8 | +25 | +18 | +35 | +30 |
| (8) | 7 | 11 | 3 | 7 | *790* | 12.03 | 1.379 | 8.8 | 0.58 | 6.60 |
| | | | 1.215 | 10.81 | 1.329 | 10.84 | 1.279 | 10.13 | 1.163 | 9.04 |
| | | | +14 | +11 | +4 | +11 | +8 | +20 | +18 | +33 |
| (9) | 6 | 10 | 1 | 5 | *840* | 13.16 | 1.667 | 9.2 | 0.58 | 6.31 |
| | | | 1.241 | 11.11 | 1.366 | 11.15 | 1.287 | 10.29 | 1.177 | 9.27 |
| | | | +34 | +19 | +22 | +18 | +29 | +28 | +42 | +42 |
| (10) | 5 | 10 | 0 | 5 | 843 | 11.47 | 1.364 | 7.9 | 0.50 | 6.34 |
| | | | 1.139 | 10.37 | 1.246 | 10.40 | 1.183 | 9.52 | 1.089 | 8.64 |
| | | | +20 | +11 | +9 | +9 | +15 | +20 | +25 | +33 |

### TABLE P.—MEDIUM PROTEIN: 6 CLASS E RECORDS, AVERAGE LENGTH 88 DAYS

**(1) Karah, '09, J, 4, 49. (2) Edith, '98, J, 10, 84. (3) Elizabeth, '00, J, 12, 70. (4) Tansy, '03, J, 8, 119. (5) Angie, '04, J, 8, 84. (6) Angie, '04, J, 9, 119.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 10 | 12 | 6 | 8 | 873 | 9.59 | 1.000 | 5.3 | 0.31 | 5.85 |
| | | | 0.958 | 9.24 | 1.030 | 9.28 | 0.948 | 8.09 | 0.895 | 7.66 |
| | | | +4 | +4 | —3 | +3 | +5 | +19 | +12 | +25 |
| (2) | 10 | 13 | 6 | 9 | 958 | 11.44 | 1.108 | 5.2 | 0.39 | 5.58 |
| | | | 1.003 | 9.80 | 1.071 | 9.84 | 0.978 | 8.46 | 0.929 | 8.11 |
| | | | +11 | +17 | +3 | +16 | +13 | +35 | +19 | +41 |
| (3) | 9 | 11 | 6 | 8 | 830 | 11.08 | 1.157 | 5.7 | 0.37 | 6.50 |
| | | | 0.991 | 9.32 | 1.066 | 9.34 | 1.002 | 8.46 | 0.928 | 7.75 |
| | | | +17 | +19 | +8 | +19 | +15 | +31 | +25 | +43 |
| (4) | 9 | 13 | 3 | 7 | 1024 | 12.88 | 1.715 | 5.6 | 0.31 | 5.50 |
| | | | 1.075 | 10.49 | 1.148 | 10.53 | 1.049 | 9.06 | 0.996 | 8.68 |
| | | | +60 | +23 | +49 | +22 | +63 | +42 | +72 | +48 |
| (5) | 7 | 10 | 3 | 6 | 1036 | 11.82 | 1.359 | 5.9 | 0.41 | 6.95 |
| | | | 1.162 | 11.17 | 1.250 | 11.21 | 1.178 | 10.22 | 1.093 | 9.31 |
| | | | +17 | +6 | +9 | +5 | +15 | +16 | +24 | +27 |
| (6) | 6 | 12 | 1 | 7 | 1080 | 9.92 | 0.975 | 3.6 | 0.23 | 6.30 |
| | | | 1.006 | 10.24 | 1.055 | 10.26 | 0.954 | 8.85 | 0.911 | 8.45 |
| | | | —3 | —3 | —8 | —3 | +2 | +12 | +7 | +18 |

### TABLE Q.—HIGH PROTEIN: 26 CLASS C RECORDS, AVERAGE LENGTH 184 DAYS

**(1) Catrina, '01, H, 6, 49. (2) Hilda, '01, J, 7, 119. (3) Vt. Una, '00, *J*, 7, 140. (4) Vt. Una, '00, J, 8, 189. (5) Yuba, '99, J, 9, 105. (6) Yuba, '99, J, 11, 210. (7) Doris, '01, J, 8, 140. (8) Vie, '02, J, 6, 210. (9) Catrina, '01, H, 7, 84. (10) Catrina, '01, H, 8, 210. (11) Dewdrop, '00, J, 12, 217. (12) Madam, '05, J, 3, 210. (13) Peggy, '05, J, 2, 210. (14) Yuba, '99, J, 13, 217. (15) Avis, '00, J, 11, 210. (16) Cherry, '00, J, 10, 210. (17) Cherry, '00, J, 12, 217. (18) Dot, '09, J, 5, 224. (19) Doris, '01, J, 10, 189. (20) Vie, '02, J, 10, 217. (21) Vt. Una, '00, *J*, 9, 210. (22) Vt. Una, '00, *J*, 10, 154. (23) Vt. Una, '00, *J*, 11, 189. (24) Lena, '03, J, 8, 216. (25) Rosel, '96, J, 15, 210. (26) Yuba, '99, J, 14, 217.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | ? | ? | 5 | 7 | 1103 | 18.69 | 2.859 | 19.9 | 0.69 | 3.47 |
| | | | 1.747 | 14.98 | 1.986 | 15.10 | 1.887 | 13.16 | 1.722 | 12.26 |
| | | | +64 | +25 | +44 | +24 | +51 | +42 | +66 | +53 |
| (2) | 5 | 9 | 2 | 6 | 953 | 14.32 | 2.000 | 10.2 | 0.46 | 4.43 |
| | | | 1.249 | 11.35 | 1.371 | 11.42 | 1.271 | 9.81 | 1.198 | 9.38 |
| | | | +60 | +26 | +46 | +25 | +57 | +46 | +67 | +53 |
| (3) | 10 | 15 | 2 | 7 | 825 | 13.18 | 2.007 | 10.3 | 0.60 | 5.83 |
| | | | 1.252 | 11.05 | 1.391 | 11.12 | 1.324 | 10.07 | 1.220 | 9.24 |
| | | | +60 | +19 | +44 | +19 | +52 | +31 | +64 | +43 |
| (4) | 5 | 11 | 1 | 7 | 840 | 16.54 | 1.900 | 12.0 | 0.72 | 6.00 |
| | | | 1.392 | 12.07 | 1.560 | 12.15 | 1.500 | 11.27 | 1.371 | 10.12 |
| | | | +36 | +37 | +22 | +36 | +27 | +47 | +39 | +64 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (5) | 7 | 11 | 4 | 8 | 1062 | 17.58 | 2.571 | 11.6 | 0.63 | 5.43 |
| | | | 1.486 | 13.34 | 1.637 | 13.42 | 1.542 | 11.88 | 1.432 | 11.11 |
| | | | +73 | +32 | +57 | +31 | +67 | +48 | +80 | +58 |
| (6) | 5 | 12 | 0 | 6 | 1080 | 14.10 | 1.967 | 10.2 | 0.53 | 5.20 |
| | | | 1.388 | 12.76 | 1.521 | 12.83 | 1.419 | 11.18 | 1.328 | 10.60 |
| | | | +41 | +11 | +29 | +10 | +39 | +26 | +48 | +33 |
| (7) | 9 | 14 | 3 | 8 | 980 | 14.15 | 2.243 | 12.2 | 0.67 | 5.49 |
| | | | 1.467 | 12.94 | 1.625 | 13.03 | 1.541 | 11.62 | 1.425 | 10.80 |
| | | | +53 | +9 | +38 | +9 | +46 | +22 | +57 | +31 |
| (8) | 6 | 13 | 0 | 5 | 982 | 18.52 | 2.810 | 19.5 | 0.88 | 4.51 |
| | | | 1.799 | 15.04 | 2.033 | 15.18 | 1.930 | 13.31 | 1.790 | 12.49 |
| | | | +56 | +23 | +38 | +22 | +46 | +39 | +57 | +48 |
| (9) | 9 | 12 | 4 | 7 | 1109 | 23.23 | 3.670 | 23.7 | 0.81 | 3.42 |
| | | | 1.938 | 16.21 | 2.222 | 16.35 | 2.126 | 14.35 | 1.938 | 13.28 |
| | | | +89 | +43 | +65 | +42 | +73 | +62 | +89 | +75 |
| (10) | 7 | 14 | 0 | 5 | 1145 | 20.89 | 3.729 | 31.2 | 1.01 | 3.24 |
| | | | 2.299 | 18.41 | 2.642 | 18.53 | 2.575 | 16.51 | 2.314 | 15.03 |
| | | | +62 | +14 | +41 | +13 | +45 | +27 | +61 | +39 |
| (11) | 6 | 13 | 0 | 6 | 808 | 13.14 | 2.364 | 15.2 | 0.76 | 5.00 |
| | | | 1.478 | 12.46 | 1.675 | 12.56 | 1.602 | 11.15 | 1.476 | 10.40 |
| | | | +60 | +5 | +41 | +4 | +48 | +18 | +60 | +26 |
| (12) | 3 | 10 | 0 | 4 | 772 | 16.12 | 2.500 | 15.0 | 0.88 | 5.90 |
| | | | 1.545 | 12.89 | 1.755 | 12.98 | 1.709 | 12.29 | 1.548 | 10.85 |
| | | | +62 | +25 | +42 | +24 | +47 | +31 | +61 | +50 |
| (13) | 2 | 9 | 0 | 5 | 722 | 13.92 | 2.430 | 19.0 | 1.08 | 5.68 |
| | | | 1.750 | 14.05 | 2.006 | 14.16 | 1.967 | 13.40 | 1.775 | 11.86 |
| | | | +39 | —1 | +21 | —2 | +24 | +4 | +37 | +17 |
| (14) | 2 | 9 | 0 | 5 | 1088 | 14.48 | 2.420 | 13.7 | 0.67 | 4.95 |
| | | | 1.584 | 14.08 | 1.762 | 14.18 | 1.658 | 12.37 | 1.534 | 11.71 |
| | | | +53 | +3 | +38 | +2 | +46 | +17 | +58 | +24 |
| (15) | 3 | 10 | 1 | 8 | 835 | 11.85 | 1.934 | 13.5 | 0.66 | 4.89 |
| | | | 1.395 | 12.00 | 1.570 | 12.09 | 1.493 | 10.66 | 1.380 | 10.00 |
| | | | +39 | —1 | +23 | —2 | +30 | +11 | +40 | +19 |
| (16) | 4 | 11 | 0 | 5 | 939 | 13.99 | 2.105 | 13.2 | 0.66 | 5.00 |
| | | | 1.449 | 12.70 | 1.621 | 12.79 | 1.532 | 11.22 | 1.423 | 10.57 |
| | | | +45 | +10 | +30 | +9 | +37 | +25 | +48 | +32 |
| (17) | 2 | 9 | 0 | 5 | 928 | 12.22 | 1.938 | 12.5 | 0.60 | 4.80 |
| | | | 1.381 | 12.17 | 1.537 | 12.26 | 1.445 | 10.67 | 1.348 | 10.10 |
| | | | +40 | 0 | +26 | 0 | +34 | +14 | +44 | +21 |
| (18) | 2 | 9 | 0 | 6 | 905 | 12.77 | 2.138 | 15.1 | 0.75 | 4.97 |
| | | | 1.540 | 13.19 | 1.736 | 13.29 | 1.653 | 11.73 | 1.527 | 11.00 |
| | | | +39 | —3 | +23 | —4 | +29 | +9 | +40 | +16 |
| (19) | 4 | 10 | 0 | 6 | 968 | 14.65 | 2.673 | 15.6 | 0.77 | 4.94 |
| | | | 1.614 | 13.89 | 1.816 | 13.99 | 1.707 | 12.34 | 1.577 | 11.58 |
| | | | +66 | +5 | +47 | +5 | +57 | +19 | +70 | +27 |
| (20) | 2 | 9 | 0 | 5 | 988 | 13.31 | 1.913 | 17.0 | 0.72 | 4.26 |
| | | | 1.635 | 13.92 | 1.831 | 14.04 | 1.730 | 12.18 | 1.609 | 11.51 |
| | | | +17 | —4 | +4 | —5 | +11 | +9 | +19 | +16 |
| (21) | 3 | 10 | 0 | 7 | 918 | 14.60 | 1.962 | 12.4 | 0.71 | 5.73 |
| | | | 1.455 | 12.71 | 1.622 | 12.79 | 1.549 | 11.64 | 1.424 | 10.63 |
| | | | +35 | +15 | +21 | +15 | +29 | +25 | +38 | +37 |
| (22) | 3 | 8 | 1 | 6 | 891 | 13.29 | 1.695 | 10.4 | 0.55 | 5.29 |
| | | | 1.269 | 11.34 | 1.404 | 11.41 | 1.322 | 10.05 | 1.230 | 9.45 |
| | | | +34 | +17 | +21 | +16 | +28 | +32 | +38 | +41 |
| (23) | 3 | 9 | 0 | 5 | 875 | 13.62 | 1.931 | 13.1 | 0.70 | 5.35 |
| | | | 1.425 | 12.32 | 1.595 | 12.42 | 1.518 | 11.05 | 1.402 | 10.29 |
| | | | +36 | +11 | +21 | +10 | +27 | +23 | +38 | +33 |
| (24) | 2 | 9 | 0 | 6 | 890 | 15.05 | 2.615 | 21.0 | 1.06 | 5.06 |
| | | | 1.883 | 15.42 | 2.156 | 15.56 | 2.079 | 13.93 | 1.904 | 12.91 |
| | | | +39 | —2 | +21 | —3 | +26 | +8 | +37 | +17 |
| (25) | 6 | 13 | 0 | 2 | 1016 | 14.34 | 2.180 | 12.5 | 0.64 | 5.15 |
| | | | 1.486 | 13.18 | 1.649 | 13.27 | 1.557 | 11.70 | 1.445 | 10.99 |
| | | | +47 | +9 | +32 | +8 | +40 | +23 | +51 | +30 |
| (26) | 2 | 9 | 0 | 5 | 1038 | 13.84 | 2.037 | 12.9 | 0.60 | 4.65 |
| | | | 1.481 | 13.20 | 1.642 | 13.29 | 1.538 | 11.53 | 1.438 | 10.94 |
| | | | +38 | +5 | +24 | +4 | +32 | +20 | +42 | +26 |

TABLE R.—HIGH PROTEIN: 16 CLASS D RECORDS, AVERAGE LENGTH 119 DAYS

(*1*) Hilda, '01, J, 6, 98. (*2*) Hilda, '01, J, 8, 210. (*3*) Rosel, '96, J, 13, 119. (*4*) Yuba, '99, J, 8, 70. (*5*) Yuba, '99, J, 10, 119. (*6*) Zeta, '99, J, 7, 98. (*7*) Zeta, '99, J, 12, 154. (*8*) Alta, '97, J, 13, 70. (*9*) Cherry, '00, J, 8, 154. (*10*) Hester, '01, J, 8, 210. (*11*) Kate, '00, J, 7, 70. (*12*) Kate, '00, J, 12, 49. (*13*) Santa Rosa, '99, J, 10, 70. (*14*) Tansy, '03, J, 5, 49. (*15*) Tansy, '03, J, 9, 189. (*16*) Madam, '05, J, 2, 175.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 12 | 16 | 2 | 6 | 954 | 13.37 | 1.765 | 8.8 | 0.40 | 4.55 |
| | | | 1.169 | 10.84 | 1.275 | 10.90 | 1.175 | 9.32 | 1.111 | 8.95 |
| | | | +51 | +24 | +38 | +23 | +50 | +43 | +59 | +49 |
| (*2*) | 4 | 11 | 0 | 0 | 988 | 14.51 | 2.219 | 9.7 | 0.42 | 4.34 |
| | | | 1.230 | 11.31 | 1.342 | 11.38 | 1.240 | 9.71 | 1.171 | 9.32 |
| | | | +81 | +28 | +66 | +27 | +79 | +49 | +90 | +55 |
| (*3*) | 10 | 14 | 3 | 7 | 1045 | 15.39 | 2.479 | 9.2 | 0.53 | 5.77 |
| | | | 1.334 | 12.32 | 1.458 | 12.37 | 1.366 | 11.00 | 1.273 | 10.26 |
| | | | +86 | +25 | +70 | +24 | +81 | +40 | +96 | +50 |
| (*4*) | 14 | 16 | 4 | 6 | 1097 | 14.74 | 1.986 | 8.2 | 0.48 | 5.81 |
| | | | 1.305 | 12.29 | 1.416 | 12.34 | 1.316 | 10.87 | 1.233 | 10.21 |
| | | | +52 | +20 | +40 | +19 | +51 | +35 | +61 | +45 |
| (*5*) | 8 | 12 | 3 | 7 | 1111 | 13.78 | 2.100 | 7.3 | 0.44 | 6.04 |
| | | | 1.267 | 12.10 | 1.369 | 12.15 | 1.269 | 10.74 | 1.191 | 10.04 |
| | | | +66 | +14 | +54 | +13 | +65 | +28 | +76 | +37 |
| (*6*) | 5 | 8 | 0 | 3 | 868 | 13.95 | 1.837 | 7.2 | 0.37 | 5.15 |
| | | | 1.054 | 9.84 | 1.148 | 9.89 | 1.064 | 8.58 | 1.000 | 8.16 |
| | | | +74 | +42 | +60 | +41 | +73 | +63 | +84 | +71 |
| (*7*) | 6 | 11 | 2 | 7 | 865 | 14.17 | 2.350 | 9.2 | 0.44 | 4.79 |
| | | | 1.144 | 10.40 | 1.259 | 10.47 | 1.172 | 9.03 | 1.100 | 8.61 |
| | | | +105 | +36 | +87 | +35 | +101 | +57 | +114 | +65 |
| (*8*) | 9 | 11 | 5 | 7 | 980 | 12.79 | 1.670 | 8.3 | 0.49 | 5.83 |
| | | | 1.230 | 11.41 | 1.342 | 11.56 | 1.255 | 10.16 | 1.171 | 9.49 |
| | | | +37 | +12 | +24 | +11 | +33 | +26 | +43 | +35 |
| (*9*) | 8 | 13 | 1 | 6 | 889 | 14.40 | 2.052 | 9.9 | 0.53 | 5.36 |
| | | | 1.236 | 11.12 | 1.365 | 11.19 | 1.283 | 9.82 | 1.194 | 9.26 |
| | | | +66 | +29 | +50 | +27 | +60 | +47 | +73 | +56 |
| (*10*) | 9 | 16 | 0 | 7 | 958 | 13.10 | 2.090 | 9.7 | 0.54 | 5.57 |
| | | | 1.291 | 11.71 | 1.418 | 11.78 | 1.332 | 10.40 | 1.240 | 9.75 |
| | | | +62 | +12 | +47 | +11 | +57 | +26 | +69 | +34 |
| (*11*) | 12 | 14 | 5 | 7 | 867 | 12.50 | 1.457 | 7.0 | 0.41 | 5.95 |
| | | | 1.076 | 10.03 | 1.174 | 10.07 | 1.099 | 9.04 | 1.024 | 8.35 |
| | | | +35 | +25 | +24 | +24 | +32 | +38 | +42 | +50 |
| (*12*) | 9 | 11 | 6 | 8 | 924 | 11.31 | 1.694 | 9.1 | 0.51 | 5.60 |
| | | | 1.239 | 11.19 | 1.348 | 11.25 | 1.264 | 9.92 | 1.178 | 9.31 |
| | | | +37 | +1 | +26 | +1 | +34 | +14 | +44 | +21 |
| (*13*) | 9 | 11 | 2 | 4 | 996 | 13.74 | 2.170 | 6.6 | 0.33 | 5.01 |
| | | | 1.093 | 10.53 | 1.179 | 10.57 | 1.080 | 9.02 | 1.025 | 8.70 |
| | | | +98 | +31 | +84 | +30 | +101 | +52 | +112 | +58 |
| (*14*) | 9 | 11 | 6 | 8 | 937 | 12.94 | 1.531 | 8.5 | 0.53 | 6.21 |
| | | | 1.247 | 11.39 | 1.361 | 11.43 | 1.291 | 10.43 | 1.190 | 9.49 |
| | | | +23 | +14 | +12 | +13 | +19 | +24 | +29 | +36 |
| (*15*) | 6 | 12 | 1 | 7 | 993 | 12.50 | 1.698 | 8.5 | 0.48 | 5.65 |
| | | | 1.252 | 11.60 | 1.367 | 11.65 | 1.279 | 10.34 | 1.193 | 9.65 |
| | | | +36 | +8 | +24 | +7 | +33 | +21 | +42 | +29 |
| (*16*) | 5 | 11 | 1 | 7 | 682 | 12.00 | 1.623 | 9.3 | 0.53 | 5.70 |
| | | | 1.087 | 9.48 | 1.212 | 9.54 | 1.158 | 8.69 | 1.064 | 7.93 |
| | | | +49 | +27 | +34 | +26 | +40 | +38 | +53 | +51 |

TABLE S.—HIGH PROTEIN: 2 CLASS E RECORDS, AVERAGE LENGTH 105 DAYS

(*1*) Fatima, '02, J, 6, 70. (*2*) Zeta, '99, J, 13, 140.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 8 | 10 | 0 | 0 | 941 | 10.92 | 1.286 | 2.9 | 0.19 | 6.41 |
| | | | 0.868 | 8.85 | 0.905 | 8.87 | 0.818 | 7.67 | 0.781 | 7.32 |
| | | | +48 | +23 | +42 | +23 | +57 | +42 | +65 | +49 |
| (*2*) | 5 | 10 | 3 | 8 | 846 | 10.53 | 1.357 | 4.5 | 0.22 | 4.90 |
| | | | 0.862 | 8.50 | 0.921 | 8.53 | 0.835 | 7.23 | 0.798 | 7.01 |
| | | | +57 | +24 | +47 | +23 | +62 | +46 | +70 | +50 |

### TABLE T.—VERY LOW PROTEIN: 3 CLASS C RECORDS, AVERAGE LENGTH 152 DAYS

(*1*) Ryllis, '07, J, 8, 140. (*2*) Monetta, '06, *J*, 9, 210. (*3*) Vt. Peony, '08, *J*, 7, 105.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 4 | 9 | 1 | 6 | *850* | 12.53 | 1.029 | 11.8 | 0.72 | 6.11 |
| | | | 1.386 | 12.06 | 1.551 | 12.13 | 1.489 | 11.24 | 1.363 | 10.11 |
| | | | —26 | +4 | —34 | +3 | —31 | +11 | —25 | +24 |
| (*2*) | 5 | 12 | 0 | 0 | *830* | 12.33 | 0.927 | 10.5 | 0.67 | 6.36 |
| | | | 1.311 | 11.48 | 1.453 | 11.53 | 1.400 | 10.77 | 1.275 | 9.60 |
| | | | —29 | +7 | —36 | +7 | —34 | +14 | —27 | +28 |
| (*3*) | 12 | 15 | 4 | 7 | *800* | 14.07 | 1.200 | 20.4 | 1.08 | 5.29 |
| | | | 1.825 | 14.72 | 2.090 | 14.87 | 2.030 | 13.56 | 1.848 | 12.39 |
| | | | —34 | —4 | —43 | —5 | —41 | +4 | —35 | +14 |

### TABLE U.—VERY LOW PROTEIN: 8 CLASS D RECORDS, AVERAGE LENGTH 116 DAYS

(*1*) Alice, '11, J, 4, 70. (*2*) Cherry, '00, J, 15, 49. (*3*) Janet, '10, J, 5, 210. (*4*) Rena, '10, J, 5, 119. (*5*) Rena, '10, J, 6, 154. (*6*) Ryllis, '07, J, 9, 140. (7) Vie, '10, J, 5, 70. (*8*) Vie, '10, J, 6, 119.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 9 | 12 | 6 | 9 | *920* | 10.77 | 0.957 | 9.5 | 0.61 | 6.43 |
| | | | 1.328 | 11.86 | 1.452 | 11.89 | 1.395 | 11.09 | 1.271 | 9.92 |
| | | | —28 | —9 | —34 | —9 | —31 | —3 | —25 | +9 |
| (*2*) | 12 | 14 | 3 | 5 | *930* | 10.33 | 0.878 | 6.1 | 0.29 | 4.77 |
| | | | 1.008 | 9.73 | 1.084 | 9.77 | 0.989 | 8.30 | 0.942 | 8.03 |
| | | | —13 | +6 | —19 | +6 | —11 | +24 | —7 | +29 |
| (*3*) | 9 | 16 | 0 | 3 | *850* | 11.96 | 0.890 | 9.5 | 0.63 | 6.65 |
| | | | 1.289 | 11.41 | 1.422 | 11.45 | 1.382 | 10.90 | 1.252 | 9.58 |
| | | | —30 | +5 | —37 | +4 | —36 | +10 | —29 | +25 |
| (*4*) | 6 | 10 | 3 | 7 | *780* | 11.24 | 0.899 | 8.1 | 0.51 | 6.30 |
| | | | 1.109 | 9.96 | 1.218 | 10.00 | 1.163 | 9.21 | 1.066 | 8.32 |
| | | | —19 | +13 | —26 | +12 | —23 | +22 | —16 | +35 |
| (*5*) | 6 | 12 | 3 | 9 | *790* | 12.08 | 0.838 | 8.9 | 0.57 | 6.41 |
| | | | 1.194 | 10.54 | 1.310 | 10.57 | 1.264 | 9.93 | 1.148 | 8.82 |
| | | | —28 | +15 | —36 | +14 | —34 | +22 | —27 | +37 |
| (*6*) | 4 | 9 | 2 | 7 | *820* | 12.64 | 0.836 | 7.9 | 0.48 | 6.08 |
| | | | 1.103 | 10.07 | 1.214 | 10.11 | 1.136 | 9.15 | 1.061 | 8.40 |
| | | | —24 | +26 | —31 | +25 | —26 | +38 | —21 | +50 |
| (7) | 8 | 12 | 5 | 9 | *850* | 13.76 | 1.171 | 9.8 | 0.70 | 7.15 |
| | | | 1.320 | 11.66 | 1.467 | 11.72 | 1.439 | 11.33 | 1.299 | 9.83 |
| | | | —11 | +18 | —20 | +17 | —19 | +22 | —10 | +40 |
| (*8*) | 8 | 12 | 3 | 7 | *830* | 12.51 | 0.874 | 8.1 | 0.57 | 7.04 |
| | | | 1.180 | 10.65 | 1.302 | 10.70 | 1.265 | 10.18 | 1.150 | 8.94 |
| | | | —26 | +17 | —33 | +16 | —31 | +23 | —24 | +40 |

### TABLE V.—VERY LOW PROTEIN: 3 CLASS E RECORDS, AVERAGE LENGTH 126 DAYS

(*1*) Vt. Peony, '08, *J*, 7, 70. (*2*) Granny, '10, J, 6, 154. (*3*) Monetta, '06, *J*, 10, 154.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (*1*) | 8 | 12 | 0 | 3 | *810* | 10.37 | 0.886 | 5.7 | 0.36 | 6.32 |
| | | | 0.963 | 9.08 | 1.040 | 9.11 | 0.973 | 8.18 | 0.906 | 7.55 |
| | | | —8 | +14 | —15 | +14 | —9 | +27 | —2 | +37 |
| (*2*) | 13 | 18 | 0 | 0 | *910* | 9.60 | 0.636 | 4.3 | 0.27 | 6.29 |
| | | | 0.936 | 9.22 | 0.994 | 9.24 | 0.912 | 8.10 | 0.861 | 7.63 |
| | | | —32 | +4 | —36 | +4 | —30 | +19 | —26 | +26 |
| (*3*) | 5 | 10 | 0 | 0 | *860* | 10.54 | 0.722 | 5.1 | 0.34 | 6.67 |
| | | | 0.979 | 9.38 | 1.060 | 9.41 | 0.998 | 8.60 | 0.925 | 7.82 |
| | | | —26 | +12 | —32 | +12 | —28 | +23 | —22 | +35 |

The vast amount of material on the foregoing pages is presented in condensed form in tables A to V, on pages 162-165, inclusive, which set forth the averages of the several groups:

The horizontal lines show the same data as in the great tables on pages 143-161, of which they are a condensation. The explanations as to their nature on page 142, hold here, except that it should be noted that the 3rd and 4th horizontal lines, each dealing with percentages, differ in this respect that the upper one is determined by direct division, using the figures immediately above, whereas, the lower one is the product of the addition of the individual percentage figures in the great tables, the product being divided by the total number. The figures are closely identical and usually the same.

SUMMATION TABLES A TO V, INCLUSIVE, BEING AVERAGES OF THE 324 RECORDS ON PAGES 143 TO 161, INCLUSIVE. FOR HEADING EXPLANATIONS SEE PAGE 142

TABLE A.—LOW PROTEIN: 34 CLASS A RECORDS, AVERAGE LENGTH 137 DAYS; AVERAGE AGE 8.6 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.5 4.8 0 | 0 | 841 | 14.98 | 1.606 | 23.20 | 1.127 | 4.90 |
| II* | 1.966 | 15.74 | 2.257 | 15.90 | 2.182 | 14.30 | 1.998 | 13.18 |
| III* | —18 | —5 | —29 | —6 | —26 | +5 | —20 | +14 |
| IV* | —18 | —4 | —28 | —5 | —25 | +5 | —19 | +15 |

TABLE B.—LOW PROTEIN: 30 CLASS B RECORDS, AVERAGE LENGTH 160 DAYS; AVERAGE AGE 7.2 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.4 5.8 0 | 2.1 | 858 | 15.61 | 1.643 | 21.12 | 1.059 | 5.03 |
| II* | 1.865 | 15.15 | 2.129 | 15.30 | 2.057 | 13.83 | 1.880 | 12.69 |
| III* | —12 | +3 | +23 | +2 | —20 | +13 | —13 | +23 |
| IV* | —11 | +4 | —22 | +3 | —19 | +13 | —11 | +24 |

TABLE C.—MEDIUM PROTEIN: 18 CLASS A RECORDS, AVERAGE LENGTH 142 DAYS; AVERAGE AGE 8.6 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.4 4.8 0 | 0.2 | 934 | 16.01 | 2.221 | 23.66 | 1.187 | 5.13 |
| II* | 2.083 | 16.83 | 2.385 | 16.99 | 2.317 | 15.55 | 2.103 | 14.09 |
| III* | +7 | —5 | —7 | —6 | —4 | +3 | +6 | +14 |
| IV* | +8 | —3 | —5 | —4 | —2 | +5 | +7 | +16 |

*I, II, III, IV, see explanation page 142. I refers to "II upper horizontal line"; II to "III middle horizontal line"; III to "IV lower horizontal line"; and IV to the paragraph at the head of this page.

[1] These captions have no relationship whatsoever to the figures in the upper horizontal line in each of the 21 tables on pages 162 to 165. They refer only to the figures in the 2nd, 3rd and 4th horizontal lines in the tables.

TABLE D.—MEDIUM PROTEIN: 29 CLASS B RECORDS, AVERAGE LENGTH 182 DAYS; AVERAGE AGE 7.3 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.7 6.4 0 | 0.3 | 954 | 15.63 | 2.137 | 19.96 | 0.998 | 5.06 |
| II* | 1.844 | 15.19 | 2.097 | 15.32 | 2.020 | 13.80 | 1.860 | 12.67 |
| III* | +16 | +3 | +2 | +2 | +6 | +13 | +16 | +23 |
| IV* | +16 | +1 | +2 | 0 | +6 | +11 | +16 | +21 |

TABLE E.—HIGH PROTEIN: 26 CLASS A RECORDS, AVERAGE LENGTH 140 DAYS; AVERAGE AGE 7.9

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.4 4.7 0 | 0 | 917 | 16.65 | 2.89 | 24.94 | 1.145 | 4.76 |
| II* | 2.078 | 16.65 | 2.384 | 16.81 | 2.311 | 15.15 | 2.108 | 13.90 |
| III* | +39 | 0 | +21 | —1 | +25 | +10 | +37 | +20 |
| IV* | +40 | 0 | +22 | —1 | +26 | +10 | +38 | +20 |

TABLE F.—HIGH PROTEIN: 26 CLASS B RECORDS, AVERAGE LENGTH 165 DAYS; AVERAGE AGE 7.3 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0 5.9 0 | 2.3 | 877 | 15.72 | 2.633 | 21.44 | 1.059 | 5.02 |
| II* | 1.890 | 15.40 | 2.159 | 15.55 | 2.093 | 14.05 | 1.909 | 12.87 |
| III* | +39 | +2 | +22 | +1 | +26 | +12 | +38 | +22 |
| IV* | +43 | +3 | +25 | +2 | +30 | +13 | +42 | +23 |

TABLE G.—VERY LOW PROTEIN: 6 CLASS A RECORDS, AVERAGE LENGTH 145 DAYS AVERAGE AGE 7.3 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.2 4.5 0 | 0 | 855 | 15.20 | 1.223 | 23.75 | 1.165 | 4.96 |
| II* | 2.005 | 16.00 | 2.301 | 16.17 | 2.236 | 14.66 | 2.032 | 13.39 |
| III* | —39 | —5 | —47 | —6 | —45 | +4 | —40 | +13 |
| IV* | —38 | —3 | —46 | —5 | —44 | +5 | —38 | +14 |

TABLE H.—VERY LOW PROTEIN: 9 CLASS B RECORDS, AVERAGE LENGTH 168 DAYS; AVERAGE AGE 6.3 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 0.6 6 0 | 2.8 | 833 | 14.58 | 1.209 | 20.93 | 1.039 | 5.13 |
| II* | 1.837 | 14.82 | 2.101 | 14.99 | 2.037 | 13.61 | 1.852 | 12.42 |
| III* | —34 | —2 | —42 | —3 | —41 | +7 | —35 | +17 |
| IV* | —34 | —1 | —42 | —2 | —40 | +8 | —34 | +19 |

TABLE I.—LOW PROTEIN: 24 CLASS C RECORDS, AVERAGE LENGTH 177 DAYS; AVERAGE AGE 8.6 YEARS

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| I* | 5.0 11.0 1.3 | 6.8 | 915 | 13.63 | 1.443 | 13.95 | 0.707 | 5.18 |
| II* | 1.489 | 12.85 | 1.666 | 12.94 | 1.588 | 11.59 | 1.463 | 10.70 |
| III* | —3 | +6 | —13 | +5 | —9 | +18 | —1 | +27 |
| IV* | —6 | +8 | —16 | +6 | —12 | +19 | —4 | +29 |

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| TABLE K.—LOW PROTEIN: 19 CLASS D RECORDS, AVERAGE LENGTH 110 DAYS; AVERAGE AGE 8.4 YEARS | | | | | | | | |
| I* | 8.1 11.9 | 2.5 5.6 | 871 | 12.30 | 1.129 | 7.90 | 0.45 | 5.72 |
| II* | 1.122 | 10.31 | 1.226 | 10.36 | 1.151 | 9.21 | 1.071 | 8.55 |
| III* | +1 | +19 | —8 | +19 | —2 | +34 | +5 | +44 |
| IV* | +1 | +19 | —8 | +19 | —2 | +34 | +5 | +44 |
| TABLE L.—LOW PROTEIN: 6 CLASS E RECORDS, AVERAGE LENGTH 113 DAYS; AVERAGE AGE 8 YEARS | | | | | | | | |
| I* | 7.3 11.5 | 1.8 6.0 | 944 | 11.60 | 1.058 | 5.1 | 0.26 | 5.14 |
| II* | 0.973 | 9.55 | 1.047 | 9.58 | 0.944 | 8.19 | 0.900 | 7.88 |
| III* | +9 | +21 | +1 | +21 | +12 | +42 | +18 | +47 |
| IV* | +9 | +33 | +3 | +21 | +13 | +42 | +18 | +48 |
| TABLE M.—LOW PROTEIN: 3 CLASS F RECORDS, AVERAGE LENGTH 210 DAYS; AVERAGE AGE 11 YEARS | | | | | | | | |
| I* | 11.7 19.3 | 3.3 10 | 930 | 14.43 | 1.43 | 10.7 | 0.56 | 5.20 |
| II* | 1.309 | 11.74 | 1.449 | 11.82 | 1.362 | 10.35 | 1.269 | 9.77 |
| III* | +9 | +23 | —1 | +22 | +5 | +40 | +13 | +48 |
| IV* | +9 | +23 | —1 | +22 | +5 | +39 | +13 | +47 |
| TABLE N.—MEDIUM PROTEIN: 20 CLASS C RECORDS, AVERAGE LENGTH 196 DAYS; AVERAGE AGE 8.6 YEARS | | | | | | | | |
| I* | 6.1 12.4 | 0.6 5.7 | 977 | 14.78 | 1.937 | 15.54 | 0.791 | 5.22 |
| II* | 1.633 | 13.99 | 1.828 | 14.09 | 1.748 | 12.65 | 1.607 | 11.67 |
| III* | +19 | +6 | +6 | +5 | +11 | +17 | +21 | +27 |
| IV* | +20 | +6 | +7 | +6 | +12 | +18 | +22 | +28 |
| TABLE O.—MEDIUM PROTEIN: 10 CLASS D RECORDS, AVERAGE LENGTH 141 DAYS; AVERAGE AGE 7.7 YEARS | | | | | | | | |
| I* | 7.7 12.3 | 2 5.6 | 921 | 12.30 | 1.465 | 8.65 | 0.494 | 5.74 |
| II* | 1.216 | 11.04 | 1.329 | 11.10 | 1.251 | 9.99 | 1.160 | 9.25 |
| III* | +20 | +11 | +10 | +11 | +17 | +23 | +26 | +33 |
| IV* | +21 | +11 | +10 | +11 | +17 | +23 | +26 | +33 |
| TABLE P.—MEDIUM PROTEIN: 6 CLASS E RECORDS, AVERAGE LENGTH 88 DAYS; AVERAGE AGE 8.5 YEARS | | | | | | | | |
| I* | 8.5 11.8 | 4.2 7.5 | 967 | 11.33 | 1.222 | 5.20 | 0.32 | 6.11 |
| II* | 1.033 | 10.04 | 1.103 | 10.08 | 1.018 | 8.86 | 0.959 | 8.33 |
| III* | +18 | +11 | +11 | +10 | +20 | +28 | +27 | +36 |
| IV* | +18 | +11 | +10 | +10 | +20 | +26 | +27 | +34 |

| | Digestible protein (Haecker)[1] | Digestible dry matter (Haecker)[1] | Digestible protein (Savage)[1] | Digestible dry matter (Savage)[1] | Digestible protein (Eckles)[1] | Digestible dry matter (Eckles)[1] | Digestible protein (Armsby)[1] | Digestible dry matter (Armsby)[1] |
|---|---|---|---|---|---|---|---|---|
| **TABLE Q.—HIGH PROTEIN: 26 CLASS C RECORDS, AVERAGE LENGTH 184 DAYS; AVERAGE AGE 8.6 YEARS** | | | | | | | | |
| I* | 4.3 10.0 | 0.9 5.8 | 949 | 15.10 | 2.33 | 15.11 | 0.723 | 4.75 |
| II* | 1.553 | 13.37 | 1.745 | 13.47 | 1.66 | 11.97 | 1.53 | 11.14 |
| III* | +50 | +13 | +34 | +12 | +40 | +26 | +52 | +36 |
| IV* | +49 | +13 | +33 | +12 | +40 | +26 | +51 | +36 |
| **TABLE R.—HIGH PROTEIN: 16 CLASS D RECORDS, AVERAGE LENGTH 119 DAYS; AVERAGE AGE 8.6 YEARS** | | | | | | | | |
| I* | 8.4 12.4 | 2.6 6.1 | 947 | 13.46 | 1.921 | 8.50 | 0.46 | 5.46 |
| II* | 1.203 | 11.10 | 1.315 | 11.16 | 1.228 | 9.82 | 1.147 | 9.22 |
| III* | +60 | +21 | +46 | +21 | +56 | +37 | +67 | +46 |
| IV* | +60 | +22 | +46 | +21 | +57 | +38 | +68 | +46 |
| **TABLE S.—HIGH PROTEIN: 2 CLASS E RECORDS, AVERAGE LENGTH 105 DAYS; AVERAGE AGE 9.5 YEARS** | | | | | | | | |
| I* | 6.5 10 | 1.5 4 | 894 | 10.73 | 1.325 | 3.70 | 0.21 | 5.66 |
| II* | 0.865 | 8.68 | 0.913 | 8.70 | 0.827 | 7.45 | 0.79 | 7.17 |
| III* | +53 | +23 | +45 | +23 | +60 | +44 | +68 | +50 |
| IV* | +53 | +24 | +45 | +23 | +60 | +44 | +68 | +50 |
| **TABLE T.—VERY LOW PROTEIN: 3 CLASS C RECORDS, AVERAGE LENGTH 152 DAYS; AVERAGE AGE 8 YEARS** | | | | | | | | |
| I* | 7 12 | 1.7 4.3 | 827 | 12.97 | 1.053 | 14.2 | 0.82 | 5.92 |
| II* | 1.507 | 12.75 | 1.698 | 12.84 | 1.64 | 11.86 | 1.495 | 10.70 |
| III* | —30 | +2 | —38 | +1 | —36 | +9 | —30 | +21 |
| IV* | —30 | +2 | —38 | +2 | —35 | +10 | —29 | +22 |
| **TABLE U.—VERY LOW PROTEIN: 8 CLASS D RECORDS, AVERAGE LENGTH 116 DAYS; AVERAGE AGE 6.9 YEARS** | | | | | | | | |
| I* | 7.8 12.1 | 3.1 7 | 846 | 11.91 | 0.919 | 8.5 | 0.55 | 6.35 |
| II* | 1.190 | 10.74 | 1.309 | 10.78 | 1.255 | 10.01 | 1.149 | 8.98 |
| III* | —23 | +11 | —30 | +11 | —27 | +19 | —20 | +33 |
| IV* | —22 | +11 | —30 | +11 | —26 | +20 | —20 | +33 |
| **TABLE V.—VERY LOW PROTEIN: 3 CLASS E RECORDS, AVERAGE LENGTH 126 DAYS; AVERAGE AGE 7.7 YEARS** | | | | | | | | |
| I* | 8.7 13.3 | 0 1 | 860 | 10.17 | 0.75 | 5 | 0.32 | 6.43 |
| II | 0.959 | 9.23 | 1.031 | 9.25 | 0.961 | 8.29 | 0.897 | 7.67 |
| III* | —22 | +10 | —27 | +10 | —22 | +23 | —16 | +33 |
| IV* | —22 | +10 | —28 | +10 | —22 | +23 | —17 | +33 |

Since the pluses and minuses are the outstanding results it seems worth while to segregate them on the ration basis in the following table, excluding the table M record, which is in a class by itself.

PLUS OR MINUS RECORDS (FROM TABLES A-V, PAGES 162 TO 165)

| Ration | Table reference (pages 162-165) | Class (pages 140-141) | Number of record | Digestible protein |  |  |  | Digestible dry matter |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Haecker | Savage | Eckles | Armsby | Haecker | Savage | Eckles | Armsby |
| Very low digestible protein | G | A | 6 | —39 | —47 | —45 | —40 | — 5 | — 6 | + 4 | +13 |
|  | H | B | 9 | —34 | —42 | —41 | —35 | — 2 | — 3 | + 7 | +17 |
|  | T | C | 3 | —30 | —38 | —36 | —30 | + 2 | + 1 | + 9 | +21 |
|  | U | D | 8 | —23 | —30 | —27 | —20 | +11 | +11 | +19 | +33 |
|  | V | E | 3 | —22 | —27 | —22 | —16 | +10 | +10 | +23 | +33 |
| Low digestible protein | A | A | 34 | —18 | —29 | —26 | —20 | — 5 | — 6 | + 5 | +14 |
|  | B | B | 30 | —12 | —23 | —20 | —13 | + 3 | + 2 | +13 | +23 |
|  | I | C | 24 | — 3 | —13 | — 9 | — 1 | + 6 | + 5 | +18 | +27 |
|  | K | D | 19 | + 1 | — 8 | — 2 | + 5 | +19 | +19 | +34 | +44 |
|  | L | E | 6 | + 9 | + 1 | +12 | +18 | +21 | +21 | +42 | +47 |
| Medium digestible protein | C | A | 18 | + 7 | — 7 | — 4 | + 6 | — 5 | — 6 | + 3 | +14 |
|  | D | B | 29 | +16 | + 2 | + 6 | +16 | + 3 | + 2 | +13 | +23 |
|  | N | C | 20 | +19 | + 6 | +11 | +21 | + 6 | + 5 | +17 | +27 |
|  | O | D | 10 | +20 | +10 | +17 | +26 | +11 | +11 | +23 | +33 |
|  | P | E | 6 | +18 | +11 | +20 | +27 | +11 | +10 | +28 | +36 |
| High digestible protein | E | A | 26 | +39 | +21 | +25 | +37 | 0 | — 1 | +10 | +20 |
|  | F | B | 26 | +39 | +22 | +26 | +38 | + 2 | + 1 | +12 | +22 |
|  | Q | C | 26 | +50 | +34 | +40 | +52 | +13 | +12 | +26 | +36 |
|  | R | D | 16 | +60 | +46 | +56 | +67 | +21 | +21 | +37 | +46 |
|  | S | E | 2 | +53 | +45 | +60 | +68 | +23 | +23 | +44 | +50 |

It is interesting to note the upward steps from class to class, that is to say, the increased nutrient intake as lactation advanced, regardless of the standard used as a yardstick. This is just what was to be expected—that as the cow advanced in lactation her maintenance and other charges tend to increase. The lower horizontal line of course means very little.

Do these 324 records shown upon the foregoing pages indicate that a sufficiency of digestible nutrients was afforded these cows?

What light does this great mass of data throw upon the question of the maintenance needs of milking cows?

What was the relation of the digestible protein contents of the four rations to maintenance, to milk making and to fœtal construction?

What was the relation of the digestible dry matter contents of the four rations to maintenance, milk making and fœtal construction?

### DIGESTIBLE PROTEIN

The digestible protein intake varied much more profoundly than did that of digestible dry matter. Necessarily so, for variance in the digestible protein content of the several rations was the crux of the matter. It constituted the raison d'être for the trials which are discussed in bulletin 225. The digestible dry matter content of each ration, in so far as it was possible, was kept reasonably uniform. The situation is readily grasped in the following condensation of the table on page 166.

| Ration | Digestible protein<br>Pluses | Digestible protein<br>Minuses | Digestible dry matter<br>Pluses | Digestible dry matter<br>Minuses |
|---|---|---|---|---|
| Very low protein | 0 | 20 | 16 | 4 |
| Low protein | 6 | 14 | 18 | 2 |
| Medium protein | 18 | 2 | 18 | 2 |
| High protein | 20 | 0 | 18 | 1 |
| | 44 | 36 | 70 | 9 |

The cows as a whole had enough of total digestible nutrients to eat, as indicated by 70 pluses in the 80 digestible dry matter records. The question arises, however, do the 36 minus marks in the 80 digestible protein records—45 percent of them—indicate that the cows as a whole received an insufficiency of digestible protein?

Let us analyze the situation:

1. *High protein ration.* The cows fed the high digestible protein ration ate much more of this nutrient than was needed for the three purposes of maintenance, milk making and fœtal construction. This is true regardless of the standard used. This is true of fresh and farrow cows, of pregnant and non-pregnant cows. The same conclusion is reached in bulletin 225, in which the fact is set forth that the high protein ration seemed distinctly inferior to its competitors as a live weight maker. The mature cows fed during a long series of years continuously on the high digestible protein diet, as a whole actually lost somewhat in the weight from their seventh year onwards. Furthermore, the cows used in the lactation alternation trials when changed from a wider to a narrower ration, on the whole lost in live weight more often than they gained and vice versa. Since these cows were egregiously overfed with digestible protein, it seems unnecessary to make further use of the data they afford except in considering the relation of the digestible dry matter content to maintenance and milk making needs.

2. *Very low protein ration.* The cows fed the very low digestible protein ration ate considerably less of this nutrient than seemed necessary for the three purposes of maintenance, milk making and fœtal construction. This is true whatever standard is applied. This is true of fresh, farrow, pregnant and non-pregnant cows. When one views such a battery of minuses as appears in the tables, ranging from —16 to —47 percent for cows making more than a modicum of milk, minuses moreover which express thus concretely the judgments of four outstanding American experts in dairy nutrition, it seems fair to assume that, as a matter of fact, these cows were under-nourished. Furthermore, in this connection may be quoted the following pertinent excerpt from bulletin 225, dealing with the effect of this very low protein ration upon cows continuously fed therewith for a considerable series of years, the very cows, furthermore, and the very records that are now under consideration.

"Seven young cows, from 4 to 8 years old, were placed on the very low protein ration in the fall of 1914 and it was fed to them for two or four lactations. Two completed two, and five, four lactations. Six of the seven weighed less in the second than the first lactation. Of the five which completed four lactations all weighed less than in the first lactations in both of the later lactations. These five cows were 4, 5, 5, 7 and 8 years old when they started in the trial. Three certainly should have increased in weight because of age. The shrinkages in the fourth lactation as compared with the first were 9, 5, 7, 5 and 3 percents. The average cow, a little less than 6 years old at the outset and weighing 850 pounds, four years later weighed only 780 pounds. The following comparison is illuminating in this connection:

| No. of cows | Fed continuously | Average at first outset | Average weight first lactation | Average weight fourth lactation | Gain or loss in weight |
|---|---|---|---|---|---|
| 7 | Low protein ration.... | 4½ | 792 | 898 | +106 |
| 4 | Medium protein ration | 6½ | 951 | 1031 | +80 |
| 4 | High protein ration... | 7 | 963 | 985 | +22 |
| 4 | Very low protein ration | 6— | 850 | 780 | —70 |

"Clearly the cows fed the very low protein ration, which normally should have gained in weight had their food intake permitted such gain, maintained their milk flows at the sacrifice of their body weights."

It is further said, touching the records of the cows listed in the lactation alternation trials, to whom the very low protein ration was fed, likewise the same cows and the same records which are used in this bulletin, that "six cows fed the very low ration during one lactation without exception weighed less during the next one than they did during the first one, four being fed the low ration and two continued on the very low one. Two cows fed the low ration during the initial and the very low one during the second lactation, weighed less during the second than during the first. Four were young cows, one seven years old and one was aged. The only plus signs occur in two cases wherein the use of a low ration followed that of a low ration. In the eight comparisons where the very low ration was fed during either lactation, the average weight during the second lactation was invariably lower than it was during the first, the average shrinkage approximating 5 percent."

It seems quite safe to assert that at no time did the cows fed the very low protein ration receive a ration sufficient as to its digestible protein content to perform the three functions of body maintenance, milk manufacture and fœtal construction. Consequently these records will not be further considered, except in so far as their digestible dry matter content is concerned.

3. *Medium protein ration.* The cows fed the medium digestible protein ration appear to have received a sufficiency of digestible protein to enable them to maintain themselves, to yield an adequate milk flow and to grow a healthy fœtus. The plus sign is in evidence everywhere, except in respect to Savage's and Eckles' requirements for the fresh, non-pregnant cow, and these shortages are only 7 and 4 percents, respectively. This judgment is borne out by the statements occurring in bulletin 225 as to the live weights of the cows fed the medium protein ration. Long continued feeding during a succession of years caused the cows to increase in live weight until their ninth year, to fall off a little in the tenth and a little more in the eleventh year. The converse of the statement made under 1 above (page 167) as to the losses and gains in live weight following changes from wide to narrow rations, holds here. It seems reasonably safe to assume that the cows fed this ration were not stinted as to digestible protein, nor, on the contrary, greatly over-supplied, except perhaps when drying off and giving less than 100 pounds of milk.

4. *Low protein ration.* The cows fed the low digestible protein ration may or may not, according to the stage of lactation, have eaten a sufficiency of digestible protein to enable them adequately to maintain themselves, to make milk and to construct their fœtuses. The four propounders of the standards of course would say "No" to the ques-

tion, did the cows receive a sufficiency of digestible protein, when looking at the records of the fresh, class A and B cows. Similarly with the cows well along in lactation and giving more than 10 pounds of milk, two would surely claim insufficiency and two a bare sufficiency. The minus sign is much in evidence (14—, 6+), and it is a sinister sign in this connection. Furthermore, three of the six pluses are little fellows. On the whole, if one looks simply at this battery of figures, one necessarily concludes that these cows, except when in the latter stages of lactation, were stinted in respect to their digestible protein intake. Yet on the other hand, the testimony adduced in bulletin 225 is quite conclusive in so far as the cow continuously fed the low protein ration is concerned. "The low protein ration carrying 1.5 pounds of digestible protein daily per 1,000-pound cow furnished ample amounts to enable the cows to hold and increase their live weights. Indeed, in this respect, it outclassed its competitors." Now the cows, concerning which this statement was made, are the same cows and the records are the same records that are being used in this connection. Furthermore, the cows thus fed as compared with those fed the medium and high protein rations gave almost or quite as much milk and they dropped equally healthy calves. It would seem then as if, the dicta of the propounders of standards to the contrary notwithstanding, the cows themselves declared that they did not suffer materially, if at all, for lack of digestible protein in so far as the maintenance of live weight was concerned or in respect to the quantity or quality of the milk flow.

5. Since the very low protein ration did not maintain live weight and the high protein ration furnished a great surplusage of digestible protein, it would seem reasonably safe to assume that, so far as digestible protein was concerned, the low or the medium protein rations are to be preferred to their two competitors, for cows in all stages of lactation. The data derived from the trials in which these two rations were used seems much more closely applicable to the determination of the question now in hand than that secured when either of the other rations were fed. Furthermore, as between the two, since the cows fed the low protein ration made almost as much as did those fed the medium protein ration and at the same time maintained their live weights full better, it would seem reasonably safe to assume that at least it stood nearly if not quite on a parity with it.

Disregarding classes D and E, for obvious reasons, the average figures for the low protein rations are: Haecker —11; Savage —23; Eckles —18; Armsby —11.

6. Speaking in extremely general terms, it would appear that when the very low protein ration was fed the average shortage in the digestible protein intake, according to the highly variable standards, was approximately ⅓; that when the low protein ration was fed it was 1/14; when the medium protein ration was fed, the surplusage was ⅛; and when the high protein ration was fed it was 3/7.

### DIGESTIBLE DRY MATTER

As has been heretofore pointed out, the digestible dry matter figures, as between the several rations, are much more uniform than are those of digestible protein, for the reason that the latter was meant to be a mutant and the former meant as nearly as possible to be an immutant. In view of the great similarity of the figures as among the various rations, the treatment in the following discussion will be on the basis of different classes, that is to say, A, B, C, D, E, instead of on the basis of different rations.

1. *Class A. Fresh cow, unserved.* The 58 fresh cows, unserved, fed on the average 4⅔ months, eating the very low, the low and the medium digestible protein rations, ate 1/20 too little digestible dry matter according to Haecker and to Savage, 1/25 too much, according to Eckles, and ⅐ too much according to Armsby, the three averages being almost absolutely identical: (—5, —5, —5; —6, —6, —6; +4, +5, +3; +13, +14, + 14).

The 26 fresh, unserved cows which were fed for 4⅔ months on the high digestible protein ration, ate just enough digestible dry matter, according to Haecker and to Savage and ⅒ and ⅕ too much according to Eckles and to Armsby, respectively.

2. *Class B. Fresh cows.* The 85 fresh cows, some of them in the early stages of pregnancy, at the close of the record periods, fed on the average 5⅔ months, receiving the low, medium and high digestible protein rations, ate a shade more than just enough digestible dry matter according to Haecker and to Savage, a bit more than ⅛ too much acording to Eckles and nearly ¼ too much according to Armsby, the three averages being closely identical: (+3, +3, +2; +2, +2, +1; +13, +13, +12; +23, +23, +22).

The 9 fresh cows to which the very low digestible protein ration was fed on the average for 5⅔ months ate a shade less than just enough digestible dry matter according to Haecker and to Savage and ¼ and ⅙ too much according to Eckles and to Armsby.

3. *Class C. Non-fresh, pregnant cows.* The 44 non-fresh, pregnant cows, averaging 5½ months in milk at the outset of the record period and more than two-thirds along in pregnancy at its close, fed on the average for about 6 months, eating the low and the medium digestible protein rations, ate 1/20 more digestible dry matter than was needed according to Haecker and to Savage, ⅙ more and ¼ more than was needed according, respectively, to Eckles and to Armsby, the figures being practically identical: (+6, +6; +5, +5; +18, +17; +27, +27).

The 26 non-fresh and pregnant cows, averaging 4½ months in milk at the outset of the record period and almost two-thirds at its close, fed the high digestible protein ration, ate ⅛ more digestible dry matter than they needed according to Haecker and to Savage and ¼ and ⅜ more than they needed according to Eckles and to Armsby.

The records of the three non-fresh, non-pregnant cows fed the very low protein ration resemble closely the records of the 85 cows listed above in Class B.

4. *Classes D and E. Non-fresh, pregnant cows yielding small amounts of milk.* The 27 non-fresh and pregnant cows, averaging 8 months in milk at the outset of the record period and about two-thirds along along in pregnancy at its close, fed the very low and the medium digestible protein rations for an average of about 4 months, ate ⅑ more digestible dry matter than they needed, according to Haecker and to Savage, and ¼ and ⅜ more than they needed according, respectively, to Eckles and to Armsby, the figures being closely alike: (+11, +11, +11, +10; +11, +10, +11, +11; +23, +28, +19, +23; +37, +36, +33, +33).

The 43 non-fresh and pregnant cows, averaging 8 months in milk, at the outset of the record period and about two-thirds along in pregnancy at its close, fed the low and high digestible protein rations for an average of nearly 4 months, ate ⅕ more digestible dry matter than Haecker or Savage suggest and ⅜ and a little less than ½ more than Eckles or Armsby, respectively, prescribe, the figures being reasonably close: (+19, +21, +21, +23; +19, +21, +21, +23; +34, +42, +37, +44; +44. +47, +46, +50).

5. Speaking in general terms, it seems reasonably clear:

*a.* That the cows when fresh at no time failed to eat enough or almost enough digestible dry matter.

*b.* That when fresh and during the early stages of pregnancy they ate a sufficiency of digestible dry matter.

*c.* That when drying off and giving 10 or more pounds of milk, they had a plentiful supply of digestible dry matter.

*d.* That when drying off and giving less than 10 pounds of milk, they received a superabundance of digestible dry matter.

*e.* That so far as digestible dry matter is concerned, it seems probable that the cows, as a whole, were fed on a somewhat higher nutritional plane than was necessary.

6. Speaking in general terms, it would appear that when, according to Haecker and to Savage, the average fresh cow ate standard amounts of digestible dry matter, she ate according to Eckles and to Armsby, respectively, approximately 1/10 and 1/5 in excess of standard amounts; and that when the average cow which was drying off ate standard amounts of digestible dry matter, according to Haecker and to Savage, she ate, according to Eckles and to Armsby, respectvely, approximately 1/7 and 1/4 more than standard amounts.

Three hundred and seventy records are available in this connection, 46 derived from the original trials and 324 from the protein experiments. They are divided as follows:

*Maintenance trials.* Sections V, 16; VI, 15; VII, 5; VIII 10—31 fed less than a year (26 in sections V-VII, on the average for 207 days, 10 in section VIII, for 280 days), 15 fed more than a year (sections V-VII, on the average for 493 days). Fed low protein ration, 15; medium protein ration, 17; high protein ration, 14.

*Protein trials.* Fresh, unserved cows 84, average length of record period 140 days; fresh cows, usually served before end of period, 94, average length of record period 170 days; non-fresh, pregnant cows 143, average length of record period 150 days; low protein 116; medium protein 83; high protein 96; very low protein 29.

The cows were in milk throughout the record periods, except in the case of the 10 pregnant cows whose records are used in section VIII. These latter records extended over a nine-month period all told, but while in milk over a period averaging 203 days. They can be used in this connection in view of the rather small draft made by the fœtus upon the maternal digestible nutrient intake.

As has been heretofore pointed out, it is less easy to deduce when one is dealing with two factors, namely, maintenance and milk, than when one is confronted by a single one, namely, maintenance. It has seemed best, in attempting to formulate a final judgment as to digestible protein, to throw overboard all the results secured when the high protein and the very low protein rations were fed, for the reasons heretofore set forth. This involves discarding 30 percent of the regular data and nearly 40 percent of the supplementary data; but there are plenty of records left, numbering 228. All are available, however, in this discussion of the total digestible nutrients.

### 1. RELATIONSHIP BETWEEN STANDARDS

As has been heretofore pointed out, speaking in general terms, the four standards bear relationship to each other about as follows, the Haecker (the first proposed—though not in its present form) being rated as 100.

| | Maintenance | | | | Milk-making | | | |
|---|---|---|---|---|---|---|---|---|
| | Haecker | Savage | Eckles (converted) | Armsby (converted) | Haecker | Savage | Eckles (converted) | Armsby (converted) |
| Digestible protein .............. | 100 | 100 | 85 | 85 | 100 | 121 | 124 | 109 |
| Total digestible nutrients....... | 100 | 100 | 82 | 82 | 100 | 102 | 100* | 85† |

*Highly variable, from 95 to 112. †Mean; lower figures 81, increasing to 88.

The two conjoined, as of course occurs in practice, were related on the basis of the 282 records as follows:

MAINTENANCE AND MILK-MAKING

| Section or tables | Number of records | Digestible protein | | | | Total digestible nutrients | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Haecker | Savage | Eckles (converted) | Armsby (converted) | Haecker | Savage | Eckles (converted) | Armsby (converted) |
| V ............. | 16 | 100 | 113 | 109 | 99 | 100 | 101 | 90 | 83 |
| VI ............ | 15 | 100 | 113 | 108 | 98 | 100 | 101 | 90 | 82 |
| VII ........... | 5 | 100 | 114 | 110 | 101 | 100 | 101 | 90 | 83 |
| VIII .......... | 10 | 100 | 111 | 106 | 98 | 100 | 101 | 91 | 83 |
| Average ....... | 46 | 100 | 113 | 108 | 99 | 100 | 101 | 90 | 83 |
| A-F, I, N, Q.... | 236 | 100 | 114 | 110 | 100 | 100 | 101 | 91 | 84 |

## 2. COMPARISONS WITH THE SEVERAL STANDARDS

The following table sets forth the situation in succinct fashion.

COMPARISONS WITH STANDARDS

| Section or table | Number of records | Digestible protein | | | | | Total digestible nutrients | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Average actual usage | Calculated usage according to | | | | Average actual usage | Calculated usage according to | | | |
| | | | Haecker | Savage | Eckles (converted) | Armsby (converted) | | Haecker | Savage | Eckles (converted) | Armsby (converted) |
| | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 128 low protein-fed cows | | | | | | | | | | | |
| Sec. V ... | 6 | 1.66 | 1.78 | 2.02 | 1.95 | 1.77 | 15.7 | 14.95 | 15.05 | 13.55 | 12.4 |
| Sec. VI .. | 5 | 1.54 | 1.71 | 1.94 | 1.86 | 1.70 | 14.5 | 14.3 | 14.4 | 12.95 | 11.85 |
| Sec. VIII. | 4 | 1.38 | 1.44 | 1.60 | 1.51 | 1.40 | 12.65 | 12.85 | 12.95 | 11.3 | 10.6 |
| Tab. A, B. | 64 | 1.62 | 1.92 | 2.19 | 2.12 | 1.94 | 15.3 | 15.45 | 15.6 | 14.05 | 12.9 |
| Tab. I ... | 24 | 1.44 | 1.49 | 1.67 | 1.59 | 1.46 | 13.65 | 12.85 | 12.95 | 11.6 | 10.7 |
| Tab. K, L. | 25 | 1.11 | 1.09 | 1.19 | 1.10 | 1.03 | 12.2 | 10.15 | 10.2 | 9.0 | 8.45 |
| 100 medium protein-fed cows | | | | | | | | | | | |
| Sec. V.... | 4 | 1.97 | 1.93 | 2.19 | 2.12 | 1.93 | 14.4 | 15.85 | 16.1 | 14.25 | 13.1 |
| Sec. VI... | 6 | 1.74 | 1.62 | 1.82 | 1.73 | 1.59 | 13.4 | 14.05 | 14.2 | 12.7 | 11.8 |
| Sec. VII.. | 3 | 2.02 | 1.97 | 2.25 | 2.17 | 1.98 | 14.8 | 16.2 | 16.35 | 14.8 | 13.5 |
| Sec. VIII. | 4 | 2.30 | 1.84 | 2.05 | 1.97 | 1.80 | 16.5 | 15.7 | 15.8 | 14.25 | 13. |
| Tab. C, D. | 47 | 2.18 | 1.95 | 2.22 | 2.14 | 1.95 | 15.8 | 15.95 | 16.1 | 14.5 | 13.25 |
| Tab. N ... | 20 | 1.94 | 1.63 | 1.83 | 1.75 | 1.61 | 14.8 | 14. | 14.1 | 12.65 | 11.65 |
| Tab. O, P.. | 16 | 1.38 | 1.15 | 1.26 | 1.16 | 1.08 | 11.9 | 10.7 | 10.7 | 9.6 | 8.95 |
| | | | % | % | % | % | | % | % | % | % |
| 128 low protein-fed cows | | | | | | | | | | | |
| Sec. V ... | 6 | .. | —7 | —18 | —15 | —6 | .. | +5 | +4 | +16 | +27 |
| Sec. VI .. | 5 | .. | —10 | —21 | —17 | —9 | .. | +1 | +1 | +12 | +27 |
| Sec. VIII. | 4 | .. | —4 | —14 | —9 | —1 | .. | —2 | —2 | +12 | +19 |
| Tab. A, B. | 64 | .. | —16 | —26 | —24 | —16 | .. | —1 | —2 | +9 | +19 |
| Tab. I ... | 24 | .. | —3 | —14 | —9 | —1 | .. | +6 | +5 | +18 | +28 |
| Tab. K, L. | 25 | .. | +2 | —7 | +1 | +8 | .. | +20 | +20 | +36 | +45 |
| 100 medium protein-fed cows | | | | | | | | | | | |
| Sec. V ... | 4 | .. | +2 | —10 | —7 | +2 | .. | —9 | —11 | +1 | +10 |
| Sec. VI .. | 6 | .. | +7 | —4 | +1 | +9 | .. | —5 | —6 | +5 | +14 |
| Sec. VII.. | 3 | .. | +3 | —10 | —7 | +2 | .. | —9 | —9 | 0 | +10 |
| Sec. VIII. | 4 | .. | +25 | +12 | +17 | +28 | .. | +5 | +4 | +16 | +27 |
| Tab. C, D. | 47 | .. | +12 | —2 | +2 | +12 | .. | —1 | —2 | +9 | +19 |
| Tab. N .. | 20 | .. | +19 | +6 | +11 | +20 | .. | +6 | +5 | +17 | +27 |
| Tab. O, P. | 16 | .. | +20 | +10 | +19 | +28 | .. | +11 | +11 | +24 | +33 |

The low protein-fed cows ate sub-standard amounts of digestible protein whether fresh or drying off and in accordance with all standards. The medium protein-fed cows, when fresh, ate slightly sub-standard amounts according to Savage, and standard or slightly super-standard amounts according to Haecker, Eckles and Armsby. When drying, they were overfed with digestible protein according to all standards.

The thirteen medium protein-fed cows, whose records are located in sections V-VII, were slightly underfed in respect to digestible dry matter according to Haecker and Savage, but amply fed according to Eckles and Armsby. The other groups, whose records are listed in the above table, ate standard or super-standard amounts according to all standards. The outcome, expressed in a very rough approximation in terms of fractions, was as follows:

| Stage of lactation | Protein ration | Digestible protein | | | | Total digestible nutrients | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Haecker | Savage | Eckles (converted) | Armsby (converted) | Haecker | Savage | Eckles (converted) | Armsby (converted) |
| Fresh | Low | —1-9 | —1-5 | —1-5 | —1-10 | 0 | 0 | +1-8 | +2-9 |
| Fresh | Medium | +1-12 | —1-20 | 0 | +1-12 | —1-25 | —1-20 | +1-20 | +1-7 |
| Drying | Low | 0 | —1-8 | —1-16 | 0 | Variable | | | |
| Drying | Medium | +1-5 | +1-10 | +1-6 | +1-4 | +1-14 | +1-14 | +1-5 | +3-10 |

With which one of these standards, if any, did the results secured in these trials most closely agree?

### DIGESTIBLE PROTEIN

The writer, as he reviews these data, does not find himself able with certainty to declare, so far as digestible protein is concerned, in favor of any one standard to the exclusion of all others. His conclusions, stated a page or two further on, are tentative. The long continued protein trials, which lasted for nearly 15 years, quite clearly demonstrated that the cows on the low protein ration maintained their bodily status quite as well and made almost as much product as did those on the medium protein ration. If then, 1.5 pounds digestible protein is enough for an average milk cow of 1,000 pounds live weight, it is quite clear that the digestible protein standard statements of Haecker and Armsby, coupled with their respective maintenance standards, afforded results not materially higher than the average usage as shown in the 128 low protein records, and especially in those secured in sections V and VIII, tables I, K, and, comprising 45 percent of the records. If, on the contrary, it is held that 2 pounds digestible protein is necessary for an average milk cow of 1,000 pounds live weight—it is not so held in bulletin 225—then clearly the Savage and the Eckles digestible protein figures, coupled with the maintenance data they suggest, more nearly approximate the results secured in the 100 medium protein records, than do the Haecker or Armsby figures.

Thirteen comparisons are available in the table on page 175. An 8 percent variation limit would seem to be a reasonable one, equivalent to 0.12 and 0.15 pounds. How many calculated results came within this limit? Haecker 7, Armsby 7, Savage 5, Eckles 5. The pluses and minuses are, Army 5 and 8, Haecker 5 and 8, Eckles 7 and 6, Savage 10 and 3. The averages may be expressed in two ways, treating each group in the last table as a unit, regardless of the number of records it contains, be it 64 or 3, the two extremes, and treating each record on a parity with all records, according to the group containing 64 records 21⅓ times the value that is accorded to that containing only three. The averages differ, but the percentages, plus and minus, are not far apart. The figures follow:

| Ration | Each group a unit | | | | | Each record a unit | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Usage | Haecker | Savage | Eckles (converted) | Armsby (converted) | Usage | Haecker | Savage | Eckles (converted) | Armsby (converted) |
| Low protein... | 1.46 | 1.57 | 1.77 | 1.69 | 1.55 | 1.48 | 1.65 | 1.86 | 1.78 | 1.64 |
| Calculation ± usage %. | | +8 | +21 | +16 | +6 | | +12 | +26 | +20 | +11 |
| Medium protein | 1.93 | 1.73 | 1.95 | 1.86 | 1.97 | 1.97 | 1.73 | 1.96 | 1.87 | 1.72 |
| Calculation ± usage %. | | —10 | +1 | —4 | —11 | | —12 | —1 | —5 | —13 |
| Mean ........ | 1.70 | 1.65 | 1.86 | 1.78 | 1.63 | 1.73 | 1.69 | 1.91 | 1.83 | 1.68 |
| Calculation ± usage %. | | —3 | +9 | +5 | —4 | | —2 | +10 | +6 | —3 |

In the first comparison the Savage standard overruns 20 or 26 percent according to the method of averaging adopted; in the latter it is a close approximation to the usage. In the former, the Haecker and Armsby figures overrun 7 to 12 percent and in the latter underrun 10 to 13 percent. In the former the Eckles figure is 16 to 20 percent in excess, in the latter 4 to 5 percent deficient. If means are taken, three of the four are within 6 percent of usage. "You pays your money and you takes your choice."

The writer, after careful study of the whole proposition, is inclined to give it as his final judgment that the Savage digestible protein figures are somewhat overhigh; that the Eckles (converted) figures are somewhat less so; that the Armsby (converted) figures are quite satisfactory when used with fresh cows and reasonably so in general; and that the Haecker (1914 form) figures afford on the whole the closest approximation to the average.

### TOTAL DIGESTIBLE NUTRIENTS

Thirteen comparisons are available. A 5 percent variation limit would seem to be a reasonable one, equivalent on a 14 pounds usage basis to 0.7 pounds. How many calculated results came within that limit? Haecker 7, Savage 7, Eckles 3, Armsby 0. The pluses and minuses are: Haecker 6 and 7; Savage 6 and 7; Eckles 0 and 12; Armsby 0 and 13. The averages, doubly stated as above indicated, follow:

| Ration | Each record a unit | | | | | Each group a unit | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Usage | Haecker | Savage | Eckles (converted) | Armsby (converted) | Usage | Haecker | Savage | Eckles (converted) | Armsby (converted) |
| Low protein... | 14. | 13.4 | 13.5 | 12.1 | 11.2 | 14.3 | 13.8 | 13.85 | 12.45 | 11.5 |
| Calculation ± usage.... | | —4 | —4 | —14 | —20 | | —3 | —3 | —13 | —20 |
| Medium protein | 14.5 | 14.6 | 14.8 | 13.3 | 12.2 | 14.75 | 14.6 | 14.65 | 13.25 | 12.15 |
| Calculation ± usage.... | | +1 | +2 | —8 | —16 | | —1 | —1 | —10 | —18 |
| Mean ........ | 14.3 | 14. | 14.2 | 12.7 | 11.7 | 14.5 | 14.2 | 14.25 | 12.85 | 11.8 |
| Calculation ± usage.... | | —2 | —1 | —11 | —18 | | —2 | —2 | —11 | —18 |

The Haecker and Savage figures approximate the actual usage more closely than do the others, the ratios being approximately: Usage 100, Savage 98.5, Haecker 98, Eckles 89, Armsby 82. But the cows as a whole were overfed, they were more than "maintained," they gained somewhat in weight. Hence the writer is not inclined to adopt the Savage data or the Haecker figures for digestible dry matter; yet on the other hand he does not feel like accepting the very low Armsby figures, notwithstanding his recognition of the latter's right to express an opinion, based as it is upon the most accurate and painstaking animal nutritional investigations made in this country. He inclines on the whole toward the medial position of Eckles; yet it should be noted that the latter's total digestible nutrient figures seem somewhat erratic in their lack of relationship to each other as the richness of the milk increases. They seem to range a little low for milks with a fat content or less than 5.5 percent and to be somewhat overhigh for milks ranging from 5.5 to 6.5 percent fat.

### 3. LIVE WEIGHTS

Obviously the records of the cows used in section VIII are not available in this phase of the discussion, although thoroughly serviceable elsewhere. There were 16 cases of gain in live weight, seven of loss and six of no change among the cows in sections V-VII, inclusive, seven records not being available. The average gain in the 16 cases was 7½ percent, the average loss in the seven cases 6 percent, the average gain in the 29 cases in which records exist is 2.6 percent (25⅔ pounds). Since the average feeding period was 11 months in length, it seems fair to conclude that the cows as a whole were maintained without material gain in live weight; that, in other words, over and above their needs in milk making, they were fed rations which did not cause large increase in live weight. Yet, on the other hand, it is clear that they were slightly over-maintained.

So far as the cows in the protein trials are concerned, which contribute 324 records, as a whole, when mature, they tended to gain in live weight as the years advanced until they became 10 years old. This is set forth in bulletin 225. It seems fairly safe to assume that during the periods of barn feeding, which alone were used in this connection, the trend was slightly to increase in live weight, that, in other words, the cows were slightly overmaintained; and this regardless of the ration fed, so be it it was not the very low protein ration.

This general conclusion is confirmed by reference to the live weight records of a score of cows located in the protein trials. These records were judged to be the lowest of the 324 in respect to the plane of nutrition—quite apart from the question as to the digestible protein content of the ration—having due regard to the milk yields. Thirteen records covered periods from 16 to 31 weeks in length and seven from 8 to 14 weeks in length. The figures follow. The weights were made on three consecutive days and at four-week intervals. The italicised record indicates the first weight made subsequent to service.

| Name | Length of period weeks | Live weights at successive 4-week periods |
|---|---|---|
| Beatrice | 16 | 1064, 1101, 1119, 1087 |
| Crystal | 31 | 849, 835, 852, *874*, 875, 854, 844, 837 |
| Theta | 30 | 750, 759, 736, 758, 756, *756*, 767, 784 |
| Ardelle | 21 | 797, 770, 747, 760, 787, 782 |
| Monetta | 20 | 800, 796, 787, 780, 790 |
| Karah | 17 | 847, 810, *817*, 832 |
| Kate | 18 | 884, 884, 868, *884*, 882 |
| Monetta | 28 | 871, 828, 814, 824, *858*, 865, 831 |
| Sheila | 8 | 872, 853 |
| Laura B | 11 | 830, 824, 806 |
| Sheila | 8 | 825, 804 |
| Laura B | 7 | 872, 870 |
| Angie | 10 | 1102, 1095, 1053 |
| Hester | 32 | 882, 902, 930, 823, *905*, 900, 932, 946 |
| Rocket | 32 | 1097, 1119, 1107, 1100, 1095, 1119, 1113, 1132 |
| Perusia Lady | 20 | 755, 760, 778, 795, 809 |
| Fyra | 32 | 1068, 1105, 1077, 1114, 1117, 1151, 1177, 1127 (calved) |
| Sheila | 12 | 838, 863, 873 |
| Elbaje | 16 | 1139, 1184, 1195, 1189 |
| Lena | 20 | 878, 827, 827, 823, 827 |

The cows whose record periods were short had recently calved and lost somewhat in live weight, as is not at all uncommon. The others, with perhaps two exceptions, at least held their own. Since these 20 cows, fed on the lowest plane of nutrition of the 324, did not lose in live weight, all the more is there reason to hold that the herd as a whole ate more than a sufficiency of total digestible nutrients.

The writer has repeatedly studied these data. He has taken up the matter and laid it down several times. He has made grievous errors in computation, discovered and corrected them; and he fervently hopes that there may be no more. He has tired of the whole proposition, has thrown it across the room and then has taken it up again after long intervals of time and resurveyed it with a somewhat fresher mind, approaching it from a different angle. He has formed tentative judgments on the basis of partial data and discarded them. And now, after much experience of this kind, he is fairly clear in his own mind touching the several standards for milk-making, i. e., including maintenance per se and lactation, under review in this section of this bulletin. He is, therefore, inclined to hold:

1. That the Haecker digestible protein figures (1914 form) are reasonably satisfactory and the closest approximation to the results secured in the present trials; and that his total digestible nutrient statements tend to run high.
2. That the Savage digestible protein figures tend to be too high, and that his total digestible nutrient statements likewise tend to be too high.

3. That the Eckles (converted) digestible protein figures are somewhat overhigh; and that his total digestible nutrient figures on the whole are reasonably satisfactory, although somewhat low for milks with a fat content of less than 5½ percent, much too high for 6½ percent milk, and erratic in their lack of relationship to each other as milk increases in richness.

4. That the Armsby (converted) digestible protein figures are reasonably satisfactory; and that his digestible dry matter figures are too low.

The Vermont Station is not through with its maintenance work. Further studies are in hand. They are not planned to last another 15 years, but may continue for two or three years. It is expected that to certain phases of this continued work much of the mine of data accumulated since 1906 and not used in the present bulletin will contribute. It seems probable that, as a result, some concrete expression may be made looking toward the revision of or the extension of our present feeding standards.

## CONCLUSIONS

It seems desirable to gather under one head the essential findings as set forth in sections II[1] to VIII and to express the same, so far as may be, in the form of generalizations.

### SECTION II. MAINTENANCE

Twenty cows were fed for from 391 to 2,701 days. The records are complete in all respects for six and incomplete for 14 cows.

Six mature cows were fed somewhat variable rations on the average for 14 months, rations which averaged to carry ⅓ to ½ more digestible protein and from 0 to ⅙ less total digestible nutrients than standards indicate. All the cows gained in live weight from 3 to 11 percent and remained in good health for from two to five years afterwards.

Ten mature cows underfed for two to four years, as judged by standards, the deficiencies ranging from 0 to ⅖ in total digestible nutrients, seemed in nowise to suffer as a result..

Four well-fed or over-fed cows either aborted or, later, proved barren. This, however, is not necessarily to be deemed cause and effect.

The writer is inclined to feel, as a result of his careful study of these data that the Haecker, Savage, modified Wolff-Lehmann and Woll-Humphrey standards for maintenance (0.7 pounds digestible protein, 7.93 pounds total digestible nutrients) are over-statements; and that the Armsby and Eckles standards in the form as stated (0.5 pounds digestible true protein, 6 therms energy) or as "converted" (0.595 pounds digestible crude protein, 6.48 pounds total digestible nutrients) provide a sufficiency of digestible protein and total digestible nutrients for the maintenance of 1,000-pound dry, non-pregnant cows.

### SECTIONS III AND IV. MAINTENANCE AND FŒTAL CONSTRUCTION

Fourteen records are available for the study of the food cost of fœtal construction. Seven cows calved normally and seven aborted. The evidence is clear that fœtal construction makes little or no draft upon the non-nitrogenous nutrient intake of the mother but a small but noticeable draft upon her digestible protein intake, equivalent to a daily usage of from 0.05 to 0.1 pounds which may amount to upwards of 10 percent of the entire protein intake extending over the entire gestation period, very much the larger part of which of course occurs during the latter part of gestation.

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[1] Section I is too incomplete to admit of use, only one valid record being secured.

## SECTIONS V, VI, VII, IX. MAINTENANCE AND LACTATION

Eighty-one cows and 370 records contribute to the study of the maintenance needs of cows in milk. A score of animals were used in the maintenance trials as such and their 46 records are listed in Sections V, VI and VII; and threescore were enlisted in the protein trials discussed in bulletin 225, furnishing 324 records applicable to the present purpose. The very volume of the data is impressive. Its careful survey leads the writer to feel:

1. That the very low protein ration was inadequate in respect to its digestible protein content, insufficient to enable the cow to make a full milk yield, to drop a full-sized calf and to maintain her full live weight; that the high protein ration furnished a surplusage of digestible protein which conduced neither to materially greater milk flow nor augmented live weight; and that the low protein ration as fed furnished a sufficiency of digestible protein and digestible dry matter for all bodily needs.

2. That the cows as a whole were fed on an overhigh plane of nutrition.

3. In respect to the applicability of current feeding standards:

(*a*) That the Haecker digestible protein figures (1914 form) are reasonably satisfactory and the closest approximation to the results secured in the present trials; and that his total digestible nutrient statemens tend to run high.

(*b*) That the Savage digestible protein figures tend to be too high, and that his total digestible nutrient statements likewise tend to be too high.

(*c*) That the Eckles (converted) digestible protein figures are somewhat overhigh; and that his total digestible nutrient figures on the whole are reasonably satisfactory, although somewhat low for milks with a fat content of less than 5½ percent, much too high for 6½ percent milk, and erratic in their lack of relationship to each other as milk increases in richness.

(*d*) That the Armsby (converted) digestible protein figures are reasonably satisfactory; and that his digestible dry matter figures are too low.

## SECTION VIII. MAINTENANCE, MILK MAKING AND FŒTAL CONSTRUCTION

The introduction of three factors into the computation increases the difficulty of deduction. However, it seems with the data in hand reasonably safe to reaffirm the statement made above in connection with Sections III and IV as to the nature and extent of the draft made upon the nutrient intake by the fœtus. The cows fed plenty, e. g., Durtje, Hazel K. (first trial) as well as those fed less bountifully, e. g., Bontje, seem to have done equally well. They all dropped healthy, vigorous, and some of them relatively heavy, calves, made fair milk yields and maintained satisfactory body status. It would seem safe to conclude that during the first two-thirds of gestation, a ration furnishing standard amounts of the several nutrients for purposes of maintenance and milk only should serve the third purpose, that is to say the early stages of fœtal construction; and that during the last third of the gestation, when almost invariably only a small amount of milk is being made or none whatever, according to the amount made, there should be fed a maintenance ration plus the amount needed for milk making and plus the equivalent of, perhaps, twice the total digestible nutrient content of the newborn calf, care being taken to see to it that this increment contains a sufficiency of digestible protein upon which ingredient the fœtus makes an especial draft. All of which, "being interpreted" means, do not forget the call of the unborn calf; and feed a little more liberally than is needed to maintain the mother.

## APPENDIX

The condensation of the tables in Sections V to VIII, inclusive, preclude the usual full statement as to the nutrient intakes given in Sections I-IV, inclusive. However, all the material is there so that one who wishes may calculate for himself—except the total dry matter. Full milk analyses were made continually. It seems worth while placing these data also on record as of possible use. Hence the following tabular matter sets forth the material which does not appear in the main tables or which may not be computed from the data there given. Of course it is understood that "total digestible nutrients" includes the "ether extract" × 2¼ and that the figure is closely similar to, though not always identical with, "digestible dry matter." No attempt is made to calculate to the 1,000 pounds live weight basis since this may be done by any one who is interested, using the data presented herewith and in the main part of the bulletin.

I. NUTRIENT INTAKES, SECTIONS I-VIII

| | | Total dry matter | Digestible dry matter | Digestible nutrients | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Crude ash | Crude protein | Crude fiber | Nitrogen-free extract | Ether extract |
| | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| I. | 1. | 17.10 | 10.78 | 0.41 | 1.16 | 2.80 | 5.79 | 0.37 |
| | 2. | 15.18 | 9.91 | 0.41 | 1.33 | 2.35 | 5.29 | 0.36 |
| | 3. | 20.29 | 13.08 | 0.53 | 1.30 | 3.13 | 7.45 | 0.50 |
| II. | 1. | 13.15 | 8.52 | 0.32 | 1.15 | 1.86 | 4.72 | 0.30 |
| | 2. | 13.85 | 8.7 | 0.40 | 0.88 | 2.19 | 4.89 | 0.28 |
| | 3. | 11.7 | 7.56 | 0.29 | 1.25 | 1.62 | 3.97 | 0.29 |
| | 4. | 10.63 | 6.76 | 0.25 | 0.70 | 1.54 | 3.97 | 0.22 |
| | 5. | 9.58 | 6.15 | 0.23 | 0.97 | 1.41 | 3.20 | 0.22 |
| | 6. | 10.75 | 6.89 | 0.26 | 0.85 | 1.56 | 3.85 | 0.22 |
| | 7. | 7.38 | 4.79 | 0.19 | 0.64 | 1.08 | 2.52 | 0.17 |
| | 8. | 7.62 | 4.72 | 0.18 | 0.47 | 1.06 | 2.81 | 0.16 |
| | 9. | 10.70 | 6.98 | 0.27 | 0.68 | 1.69 | 4.04 | 0.22 |
| | 10. | 9.58 | 6.10 | 0.25 | 0.71 | 1.50 | 3.37 | 0.19 |
| | 11. | 9.32 | 6.00 | 0.24 | 0.77 | 1.37 | 3.36 | 0.19 |
| | 12. | 9.42 | 5.11 | 0.20 | 0.67 | 1.39 | 2.61 | 0.16 |
| | 13. | 9.82 | 6.39 | 0.25 | 0.94 | 1.56 | 3.27 | 0.25 |
| | 14. | 9.18 | 5.91 | 0.24 | 0.82 | 1.44 | 3.13 | 0.22 |
| | 15. | 11.73 | 7.61 | 0.31 | 0.88 | 1.89 | 4.17 | 0.25 |
| | 16. | 8.88 | 5.58 | 0.23 | 0.51 | 1.38 | 3.23 | 0.19 |
| | 17. | 9.52 | 6.10 | 0.25 | 0.73 | 1.46 | 3.37 | 0.21 |
| | 18. | 15.78 | 10.28 | 0.40 | 1.30 | 2.24 | 5.79 | 0.39 |
| | 19. | 15.92 | 10.22 | 0.40 | 1.13 | 2.28 | 5.94 | 0.36 |
| | 20. | 9.18 | 5.82 | 0.23 | 0.58 | 1.39 | 3.35 | 0.19 |
| Average | | 10.68 | 6.80 | 0.27 | 0.83 | 1.59 | 3.79 | 0.23 |
| Three grade Holsteins | | 12.90 | 8.26 | 0.34 | 1.10 | 1.89 | 4.53 | 0.29 |
| Three grade and registered Ayrshires | | 8.71 | 5.57 | 0.22 | 0.64 | 1.32 | 3.08 | 0.18 |
| Fourteen grade Jerseys | | 10.62 | 6.76 | 0.26 | 0.81 | 1.59 | 3.77 | 0.23 |
| III. | 1. | 11.65 | 7.45 | 0.28 | 0.73 | 1.78 | 4.28 | 0.24 |
| | 2. | 12.67 | 8.28 | 0.34 | 1.33 | 1.80 | 4.26 | 0.33 |
| | 3. | 9.92 | 6.37 | 0.27 | 0.66 | 1.45 | 3.72 | 0.23 |
| | 4. | 6.40 | 4.20 | 0.19 | 0.73 | 0.94 | 2.07 | 0.17 |
| | 5. | 6.80 | 4.40 | 0.21 | 0.47 | 1.10 | 2.40 | 0.18 |
| | 6. | 9.68 | 6.30 | 0.23 | 0.97 | 1.44 | 3.37 | 0.24 |
| | 7. | 20.22 | 13.12 | 0.58 | 2.07 | 3.21 | 6.44 | 0.61 |
| Average | | 11.15 | 7.17 | 0.30 | 1.00 | 1.67 | 3.80 | 0.29 |
| Two grade Holsteins | | 12.16 | 7.84 | 0.31 | 1.03 | 1.79 | 4.26 | 0.29 |
| Five grade Jerseys | | 10.69 | 6.90 | 0.30 | 0.98 | 1.63 | 3.61 | 0.29 |
| IV. | 1. | 11.38 | 7.35 | 0.32 | 0.95 | 1.65 | 4.05 | 0.24 |
| | 2. | 18.68 | 11.90 | 0.44 | 1.52 | 2.70 | 6.65 | 0.38 |
| | 3. | 7.58 | 4.82 | 0.22 | 0.68 | 1.05 | 2.62 | 0.17 |
| | 4. | 6.58 | 4.30 | 0.15 | 0.66 | 0.93 | 2.28 | 0.14 |
| | 5. | 9.58 | 6.18 | 0.23 | 0.73 | 1.48 | 3.37 | 0.22 |
| | 6. | 10.70 | 6.95 | 0.30 | 1.10 | 1.69 | 3.46 | 0.32 |
| | 7. | 18.08 | 11.68 | 0.43 | 1.48 | 2.64 | 6.50 | 0.36 |
| Average | | 11.80 | 7.53 | 0.30 | 1.01 | 1.74 | 4.09 | 0.26 |
| Two grade Holsteins | | 15.03 | 9.53 | 0.38 | 1.24 | 2.18 | 5.25 | 0.31 |
| Five grade Jerseys | | 10.50 | 6.74 | 0.27 | 0.92 | 1.56 | 3.63 | 0.24 |

|  | Group number | Total dry matter | Digestible dry matter | Digestible nutrients |  |  |  |  | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Crude ash | Crude protein | Crude fiber | Nitrogen-free extract | Ether extract |  |  |  |  |  |  |
|  |  | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| V. 1. | I | 26.67 | 17.10 | 0.61 | 2.55 | 3.70 | 9.54 | 0.59 | 35. | 4.30 | 1.17 | 1.04 | 1.87 | 0.26 |
| 2. | I | 32.11 | 20.77 | 0.76 | 2.09 | 4.38 | 12.59 | 0.73 | 34.6 | 4.07 | 1.12 | 1.01 | 1.66 | 0.27 |
| 3. | I | 20.05 | 13.28 | 0.48 | 1.53 | 2.73 | 7.89 | 0.50 | 25. | 2.75 | 0.69 | 0.61 | 1.24 | 0.18 |
| 4. | I | 29.15 | 18.81 | 0.80 | 3.33 | 4.12 | 9.72 | 0.79 | 31.8 | 3.88 | 1.08 | 0.97 | 1.57 | 0.23 |
| 5. | III | 24.78 | 15.85 | 0.62 | 1.55 | 3.77 | 9.23 | 0.48 | 14.4 | 2.10 | 0.74 | 0.56 | 0.67 | 0.12 |
| 6. | II | 23.47 | 15.23 | 0.62 | 1.67 | 3.40 | 8.65 | 0.59 | 19.6 | 2.96 | 1.06 | 0.76 | 0.99 | 0.15 |
| 7. | II | 21.43 | 13.98 | 0.50 | 1.56 | 2.86 | 8.32 | 0.53 | 24.3 | 3.42 | 1.13 | 0.88 | 1.24 | 0.18 |
| 8. | III | 18.89 | 12.33 | 0.48 | 2.02 | 2.71 | 6.33 | 0.48 | 12.15 | 1.85 | 0.68 | 0.49 | 0.58 | 0.10 |
| 9. | II | 24.29 | 16.10 | 0.62 | 2.60 | 3.55 | 8.25 | 0.70 | 25. | 3.58 | 1.21 | 0.93 | 1.22 | 0.19 |
| 10. | III | 23.40 | 15.00 | 0.60 | 1.82 | 3.57 | 8.22 | 0.53 | 10.55 | 1.70 | 0.67 | 0.46 | 0.48 | 0.08 |
| 11. | II | 22.62 | 14.87 | 0.50 | 2.12 | 3.13 | 8.21 | 0.50 | 20.1 | 3.00 | 1.09 | 0.78 | 0.97 | 0.16 |
| 12. | III | 22.90 | 14.88 | 0.56 | 1.58 | 3.30 | 8.38 | 0.65 | 16.8 | 2.34 | 0.69 | 0.63 | 0.88 | 0.13 |
| 13. | III | 16.47 | 10.58 | 0.42 | 1.41 | 2.45 | 5.76 | 0.45 | 12.25 | 1.40 | 0.42 | 0.35 | 0.55 | 0.09 |
| 14. | III | 19.13 | 12.70 | 0.44 | 2.03 | 2.68 | 6.57 | 0.63 | 12.45 | 1.86 | 0.66 | 0.49 | 0.61 | 0.10 |
| 15. | II | 20.94 | 13.78 | 0.60 | 1.95 | 3.52 | 7.15 | 0.52 | 10.45 | 1.44 | 0.50 | 0.39 | 0.48 | 0.07 |
| 16. | III | 17.56 | 11.30 | 0.46 | 1.79 | 2.74 | 5.71 | 0.46 | 8.05 | 1.16 | 0.41 | 0.31 | 0.39 | 0.06 |
| Average |  | 22.74 | 14.82 | 0.57 | 1.98 | 3.29 | 8.16 | 0.56 | 19.5 | 2.61 | 0.83 | 0.66 | 0.96 | 0.14 |
| Group I |  | 27. | 17.50 | 0.66 | 2.38 | 3.73 | 9.94 | 0.65 | 31.6 | 3.75 | 1.02 | 0.89 | 1.58 | 0.23 |
| Group II |  | 22.55 | 14.80 | 0.57 | 1.98 | 3.29 | 8.12 | 0.57 | 19.9 | 2.88 | 0.99 | 0.75 | 0.99 | 0.15 |
| Group III |  | 20.45 | 13.25 | 0.51 | 1.74 | 3.03 | 7.17 | 0.51 | 12.4 | 1.77 | 0.61 | 0.47 | 0.59 | 0.10 |
| VI. 1. | I | 29.13 | 18.65 | 0.75 | 2.38 | 4.90 | 10.16 | 0.55 | 22.45 | 2.75 | 0.78 | 0.68 | 1.14 | 0.17 |
| 2. | I | 21.43 | 13.77 | 0.51 | 1.73 | 3.30 | 7.54 | 0.55 | 14.9 | 1.73 | 0.51 | 0.42 | 0.72 | 0.10 |
| 3. | I | 30.49 | 19.78 | 0.80 | 2.13 | 4.15 | 11.89 | 0.72 | 30.1 | 3.54 | 1.03 | 0.87 | 1.44 | 0.21 |
| 4. | II | 23.28 | 15. | 0.55 | 1.63 | 3.22 | 8.93 | 0.64 | 24. | 2.86 | 0.82 | 0.69 | 1.18 | 0.17 |
| 5. | I | 31.46 | 20.22 | 0.79 | 3.18 | 4.61 | 10.56 | 0.76 | 27.1 | 3.23 | 0.90 | 0.86 | 1.25 | 0.21 |
| 6. | III | 21.20 | 13.50 | 0.49 | 1.93 | 2.91 | 7.46 | 0.63 | 16.45 | 2.54 | 0.99 | 0.65 | 0.80 | 0.13 |
| 7. | III | 17.36 | 11.38 | 0.40 | 1.93 | 2.27 | 6.01 | 0.49 | 16.65 | 2.12 | 0.63 | 0.54 | 0.81 | 0.11 |
| 8. | III | 17.12 | 11.28 | 0.39 | 1.23 | 2.42 | 6.65 | 0.41 | 13.7 | 2.12 | 0.82 | 0.52 | 0.65 | 0.11 |
| 9. | III | 16.13 | 10.48 | 0.38 | 1.42 | 2.33 | 5.76 | 0.42 | 13.3 | 1.91 | 0.69 | 0.49 | 0.63 | 0.10 |
| 10. | III | 21.25 | 13.45 | 0.56 | 1.40 | 2.94 | 7.95 | 0.53 | 9.55 | 1.44 | 0.52 | 0.33 | 0.48 | 0.08 |
| 11. | III | 18.73 | 12.12 | 0.45 | 1.92 | 2.74 | 6.44 | 0.40 | 13. | 1.88 | 0.66 | 0.47 | 0.64 | 0.10 |
| 12. | III | 18.59 | 12.00 | 0.46 | 1.91 | 2.69 | 6.53 | 0.43 | 13.7 | 2.16 | 0.79 | 0.55 | 0.74 | 0.11 |
| 13. | III | 19.52 | 12.42 | 0.47 | 1.50 | 2.94 | 7.13 | 0.34 | 12.45 | 1.88 | 0.71 | 0.48 | 0.62 | 0.09 |
| 14. | III | 17.67 | 11.38 | 0.42 | 1.45 | 2.58 | 6.48 | 0.33 | 12.3 | 1.83 | 0.68 | 0.46 | 0.59 | 0.10 |
| 15. | III | 20.45 | 13.04 | 0.49 | 1.33 | 2.93 | 7.87 | 0.41 | 15.8 | 2.38 | 0.85 | 0.59 | 0.82 | 0.13 |
| Average |  | 21.59 | 13.91 | 0.53 | 1.81 | 3.13 | 7.83 | 0.51 | 17.06 | 2.29 | 0.76 | 0.58 | 0.84 | 0.13 |
| Group I |  | 28.13 | 18.11 | 0.71 | 2.36 | 4.24 | 10.04 | 0.65 | 23.65 | 2.81 | 0.81 | 0.71 | 1.14 | 0.17 |
| Group II |  | 23.28 | 15. | 0.55 | 1.63 | 3.22 | 8.93 | 0.54 | 23.7 | 2.86 | 0.82 | 0.69 | 1.18 | 0.17 |
| Group III |  | 18.80 | 12.11 | 0.45 | 1.60 | 2.68 | 6.83 | 0.44 | 13.69 | 2.03 | 0.72 | 0.51 | 0.68 | 0.11 |
| VII. 1. | .. | 29.10 | 18.60 | 0.72 | 2.61 | 4.81 | 9.85 | 0.54 | 31.85 | 3.81 | 1.09 | 0.93 | 1.54 | 0.22 |
| 2. | .. | 21.59 | 13.97 | 0.54 | 2.01 | 3.01 | 7.64 | 0.55 | 23.5 | 3.35 | 1.24 | 0.82 | 1.15 | 0.16 |
| 3. | .. | 21.38 | 14.05 | 0.52 | 2.25 | 3.05 | 7.42 | 0.57 | 15.75 | 2.22 | 0.79 | 0.58 | 0.76 | 0.11 |
| 4. | .. | 22.71 | 14.65 | 0.59 | 2.4 | 3.45 | 7.43 | 0.62 | 17.1 | 2.40* | 0.85* | 0.60* | 0.82* | 0.13* |
| 6. | .. | 18.50 | 11.85 | 0.45 | 1.43 | 2.79 | 6.77 | 0.32 | 11.4 | 1.77* | 0.68* | 0.44* | 0.56* | 0.09* |
| Average four grade Jerseys and one grade Holstein |  | 22.65 | 14.63 | 0.56 | 2.14 | 3.42 | 7.82 | 0.56 | 19.9 | 2.71 | 0.93 | 0.67 | 0.97 | 0.14 |
| Average four grade Jerseys |  | 21.05 | 13.63 | 0.52 | 2.02 | 3.08 | 7.32 | 0.52 | 16.9 | 2.44 | 0.89 | 0.61 | 0.82 | 0.12 |

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*Hypothetical—no analyses made.

| Group number | Total dry matter | Digestible dry matter | Digestible nutrients | | | | | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Crude ash | Crude protein | Crude fiber | Nitrogen-free extract | Ether extract | | | | | | |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VIII. 1. .. | 26.84 | 17.2 | 0.73 | 2.29 | 4.08 | 9.23 | 0.54 | 18.25 | 2.31 | 0.67 | 0.60 | 0.91 | 0.14 |
| 2. .. | 25.04 | 16.24 | 0.61 | 2.22 | 3.53 | 9.00 | 0.57 | 20.3 | 2.36 | 0.66 | 0.61 | 0.96 | 0.14 |
| 3. .. | 17.19 | 11.15 | 0.40 | 1.06 | 2.79 | 6.28 | 0.35 | 8.35 | 1.04 | 0.31 | 0.28 | 0.39 | 0.06 |
| 4. .. | 17.33 | 11.47 | 0.38 | 1.37 | 1.99 | 7.17 | 0.39 | 10.45 | 1.22 | 0.34 | 0.30 | 0.51 | 0.07 |
| 5. .. | 21.57 | 13.73 | 0.51 | 1.91 | 3.39 | 7.25 | 0.47 | 4.95 | 0.60 | 0.17 | 0.17 | 0.22 | 0.04 |
| 6. .. | 18.92 | 12.18 | 0.48 | 1.28 | 2.93 | 6.86 | 0.39 | 6.9 | 1.01 | 0.36 | 0.28 | 0.31 | 0.05 |
| 7. .. | 20.35 | 13.28 | 0.50 | 1.46 | 2.88 | 7.69 | 0.48 | 12.8 | 1.77 | 0.65 | 0.46 | 0.59 | 0.09 |
| 8. .. | 22.49 | 14.4 | 0.60 | 2.16 | 3.45 | 7.45 | 0.53 | 10.85 | 1.80 | 0.67 | 0.50 | 0.51 | 0.09 |
| 9. .. | 22.48 | 15.00 | 0.65 | 1.95 | 3.58 | 8.10 | 0.49 | 11.2 | 1.81 | 0.70 | 0.49 | 0.54 | 0.09 |
| 10. .. | 19.42 | 12.68 | 0.48 | 1.69 | 2.79 | 7.03 | 0.44 | 8.8 | 1.24 | 0.49 | 0.35 | 0.36 | 0.06 |
| **Average** | 21.16 | 13.74 | 0.54 | 1.75 | 3.15 | 7.61 | 0.47 | 11.21 | 1.52 | 0.50 | 0.41 | 0.53 | 0.09 |
| **Five grade Holstein** | 21.59 | 13.95 | 0.53 | 1.73 | 3.16 | 7.79 | 0.46 | 12.44 | 1.51 | 0.43 | 0.39 | 0.60 | 0.09 |
| **Five grade Jerseys** | 20.73 | 13.53 | 0.54 | 1.77 | 3.13 | 7.43 | 0.47 | 9.98 | 1.53 | 0.57 | 0.42 | 0.46 | 0.08 |

II. TOTAL DRY MATTER INTAKES: MILK ANALYSES, SECTIONS V-VIII

| Weeks | Total dry matter in food | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash | Weeks | Total dry matter in food | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| V. 1. | | | | | | | | V. 8. | | | | | | | |
| 8 | 25.9 | 35.4 | 4.53 | 1.20 | 1.09 | 2.04 | 0.27 | 4 | 27.2 | 16.5 | 2.58 | 0.98 | 0.72 | 0.82 | 0.14 |
| 3 | 27.4 | 33.8 | 3.94 | 1.07 | 0.92 | 1.78 | 0.23 | 5 | 22.6 | 13.4 | 2.16 | 0.79 | 0.59 | 0.67 | 0.12 |
| V. 2. | | | | | | | | 1 | 21.1 | 11.7 | 1.77 | 0.66 | 0.50 | 0.53 | 0.10 |
| 1 | 27.2 | 26.1 | 2.93 | 0.77 | 0.76 | 1.29 | 0.19 | 5 | 17.6 | 10.5 | 1.61 | 0.60 | 0.45 | 0.48 | 0.09 |
| 2 | 31.4 | 36. | 4.30 | 1.15 | 1.07 | 1.79 | 0.27 | 1 | 16.8 | 9.6 | 1.51 | 0.59 | 0.40 | 0.44 | 0.07 |
| 12 | 33.4 | 35.7 | 4.21 | 1.14 | 1.06 | 1.74 | 0.28 | 5 | 16.2 | 9.1 | 1.45 | 0.56 | 0.39 | 0.44 | 0.07 |
| 7 | 34.5 | 34. | 4.10 | 1.15 | 1.04 | 1.71 | 0.25 | 1 | 15.8 | 8.6 | 1.36 | 0.52 | 0.37 | 0.42 | 0.07 |
| V. 3. | | | | | | | | 14 | 15.4 | 7.6 | 1.17 | 0.46 | 0.32 | 0.34 | 0.06 |
| 1 | 17.9 | 13. | 1.54 | 0.43 | 0.31 | 0.67 | 0.10 | 1 | 14.9 | 4.3 | 0.61 | 0.22 | 0.17 | 0.19 | 0.03 |
| 1 | 20.5 | 31.1 | 3.60 | 0.96 | 0.73 | 1.62 | 0.22 | V. 9. | | | | | | | |
| 2 | 21. | 31.6 | 3.51 | 0.87 | 0.76 | 1.62 | 0.23 | 1 | 16.9 | 16.4 | 2.21 | 0.69 | 0.69 | 0.70 | 0.13 |
| 8 | 19.8 | 24.7 | 2.61 | 0.65 | 0.55 | 1.24 | 0.16 | 2 | 20.8 | 29.6 | 4.04 | 1.34 | 1.24 | 1.27 | 0.25 |
| 3 | 20.5 | 17.4 | 1.94 | 0.54 | 0.42 | 0.87 | 0.13 | 10 | 24.1 | 27.8 | 3.82 | 1.25 | 0.96 | 1.39 | [illegible] |
| V. 4. | | | | | | | | 2 | 25.5 | 25. | 3.39 | 1.18 | 0.86 | 1.18 | 0.17 |
| 1 | 25.8 | 29. | 3.86 | 1.09 | 0.84 | 1.51 | 0.21 | 3 | 30.3 | 24.2 | 3.38 | 1.20 | 0.87 | 1.13 | 0.19 |
| 1 | 30.1 | 46.7 | 6.13 | 1.74 | 1.35 | 2.44 | 0.35 | 7 | 29.1 | 21.3 | 3.30 | 1.21 | 0.87 | 1.06 | 0.17 |
| 10 | 31.6 | 38. | 4.79 | 1.39 | 1.11 | 1.96 | 0.27 | V. 10. | | | | | | | |
| 8 | 31.5 | 32.5 | 3.82 | 0.99 | 1.04 | 1.55 | 0.24 | 3 | 28.2 | 17.7 | 2.79 | 1.24 | 0.66 | 0.78 | 0.14 |
| 6 | 30.5 | 27.1 | 3.22 | 0.86 | 0.87 | 1.34 | 0.19 | 4 | 36.1 | 15.4 | 2.39 | 0.94 | 0.58 | 0.72 | 0.11 |
| 7 | 28. | 24.4 | 2.89 | 0.83 | 0.78 | 1.12 | 0.18 | 1 | 30.8 | 12.3 | 1.91 | 0.74 | 0.49 | 0.61 | [illegible] |
| V. 5. | | | | | | | | 1 | 31.8 | 14.4 | 2.31 | 0.94 | 0.55 | 0.71 | 0.10 |
| 1 | 23.8 | 13.3 | 1.86 | 0.61 | 0.53 | 0.61 | 0.10 | 1 | 29.6 | 15.1 | 2.43 | 0.97 | 0.58 | 0.75 | [illegible] |
| 1 | 26.1 | 23.9 | 3.34 | 1.09 | 0.93 | 1.12 | 0.21 | 5 | 30.2 | 12.4 | 2.03 | 0.77 | 0.56 | 0.59 | [illegible] |
| 4 | 33.6 | 25.1 | 3.50 | 1.17 | 0.93 | 1.21 | 0.21 | 1 | 28.2 | 11.4 | 1.84 | 0.69 | 0.49 | 0.54 | 0.10 |
| 1 | 28.3 | 23.3 | 3.31 | 1.13 | 0.81 | 1.17 | 0.17 | 3 | 25.4 | 12.4 | 1.95 | 0.73 | 0.55 | 0.54 | 0.10 |
| 2 | 30.2 | 25.5 | 3.29 | 1.12 | 0.82 | 1.17 | 0.19 | 1 | 24.1 | 11.3 | 1.79 | 0.66 | 0.49 | 0.56 | [illegible] |
| 9 | 30.2 | 20.3 | 3.04 | 1.08 | 0.81 | 0.99 | 0.15 | 4 | 22.6 | 10.7 | 1.71 | 0.65 | 0.49 | 0.49 | [illegible] |
| 1 | 28.9 | 19.1 | 2.89 | 1.03 | 0.76 | 0.89 | 0.16 | 1 | 23.8 | 10.1 | 1.74 | 0.71 | 0.50 | 0.43 | [illegible] |
| 5 | 27.9 | 17.2 | 2.64 | 0.96 | 0.69 | 0.86 | 0.14 | 1 | 23.1 | 9. | 1.60 | 0.70 | 0.43 | 0.39 | [illegible] |
| 1 | 28.3 | 15. | 2.21 | 0.79 | 0.59 | 0.69 | 0.11 | 5 | 22.5 | 8.9 | 1.44 | 0.58 | 0.42 | 0.38 | [illegible] |
| 5 | 26.1 | 11.3 | 1.70 | 0.64 | 0.46 | 0.50 | 0.09 | 1 | 21.9 | 8.5 | 1.37 | 0.50 | 0.40 | 0.37 | [illegible] |
| 1 | 24.7 | 8.4 | 1.20 | 0.44 | 0.34 | 0.34 | 0.07 | 8 | 21.3 | 7.4 | 1.22 | 0.49 | 0.35 | 0.33 | [illegible] |
| 4 | 23.3 | 7.4 | 1.06 | 0.39 | 0.30 | 0.32 | 0.06 | 6 | 20.6 | 6.6 | 1.01 | 0.38 | 0.30 | 0.31 | 0.05 |
| 10 | 21.6 | 5.9 | 0.83 | 0.31 | 0.23 | 0.24 | 0.05 | 1 | 18.3 | 4.9 | 0.73 | 0.29 | 0.21 | 0.24 | [illegible] |
| 2 | 19.2 | 4.9 | 0.70 | 0.26 | 0.20 | 0.20 | 0.04 | V. 11. | | | | | | | |
| V. 6. | | | | | | | | 7 | 22.5 | 25.9 | 3.51 | 1.15 | 0.68 | 1.45 | [illegible] |
| 2 | 18.7 | 16.7 | 2.42 | 0.82 | 0.67 | 0.81 | 0.13 | 16 | 23.1 | 17.5 | 2.69 | 1.03 | 0.69 | 0.86 | [illegible] |
| 2 | 21.2 | 22.2 | 3.32 | 1.15 | 0.89 | 1.08 | 0.17 | V. 12. | | | | | | | |
| 1 | 27.1 | 22.1 | 3.27 | 1.18 | 0.89 | 1.07 | 0.17 | 2 | 16.6 | 30.8 | 4.31 | 1.42 | 0.98 | 1.69 | [illegible] |
| 1 | 29.1 | 19.1 | 3.29 | 1.21 | 0.80 | 1.11 | 0.17 | 3 | 21.7 | 28.5 | 3.78 | 1.16 | 0.90 | 1.54 | [illegible] |
| 3 | 27.3 | 21.9 | 3.36 | 1.26 | 0.79 | 1.16 | 0.17 | 2 | 22.8 | 24.5 | 3.22 | 0.91 | 0.79 | 1.37 | [illegible] |
| 14 | 24.9 | 20. | 3.04 | 1.07 | 0.77 | 1.02 | 0.15 | 5 | 25.8 | 22.2 | 3.05 | 0.87 | 0.87 | 1.17 | [illegible] |
| 4 | 23.7 | 15.8 | 2.39 | 0.86 | 0.66 | 0.75 | 0.11 | 5 | 26.9 | 19.9 | 2.72 | 0.79 | 0.79 | 1.00 | [illegible] |
| V. 7. | | | | | | | | 5 | 24.4 | 12.9 | 1.83 | 0.54 | 0.53 | 0.64 | [illegible] |
| 1 | 20.8 | 22.3 | 3.24 | 1.04 | 1.00 | 1.04 | 0.19 | 5 | 22.6 | 5.2 | 0.77 | 0.23 | 0.25 | 0.24 | [illegible] |
| 7 | 22.5 | 24.6 | 3.49 | 1.14 | 0.86 | 1.30 | 0.18 | 3 | 19.9 | 2.1 | 0.28 | 0.08 | 0.08 | 0.08 | [illegible] |
| V. 8. | | | | | | | | V. 13. | | | | | | | |
| 1 | 27.6 | 18.4 | 2.54 | 0.81 | 0.69 | 0.87 | 0.16 | 1 | 12.4 | 20. | 2.44 | 0.75 | 0.57 | 0.97 | [illegible] |
| 3 | 26.1 | 19. | 2.69 | 0.90 | 0.73 | 0.92 | 0.15 | 7 | 16.8 | 29.8 | 3.51 | 1.06 | 0.82 | 1.45 | [illegible] |
| 4 | 32.1 | 20.4 | 2.97 | 1.03 | 0.77 | 0.97 | 0.18 | 5 | 23.1 | 16.6 | 1.94 | 0.57 | 0.52 | 0.73 | [illegible] |
| 1 | 28.3 | 16.3 | 2.43 | 0.87 | 0.62 | 0.83 | 0.12 | 5 | 20.9 | 11.6 | 1.35 | 0.40 | 0.35 | 0.53 | [illegible] |
| 1 | 30.1 | 18.4 | 2.74 | 0.99 | 0.69 | 0.91 | 0.12 | 5 | 18.3 | 9.2 | 1.01 | 0.28 | 0.27 | 0.39 | [illegible] |
| 1 | 28.2 | 18.1 | 2.70 | 0.97 | 0.69 | 0.90 | 0.12 | 5 | 16. | 8. | 0.88 | 0.24 | 0.24 | 0.32 | [illegible] |

| Weeks | Total dry matter in food | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| V. 13. | | | | | | | |
| 5 | 17. | 6.9 | 0.78 | 0.23 | 0.20 | 0.29 | 0.05 |
| 2 | 16.7 | 6.2 | 0.65 | 0.19 | 0.18 | 0.23 | 0.04 |
| 3 | 15.2 | 5.5 | 0.58 | 0.18 | 0.16 | 0.20 | 0.04 |
| 3 | 11.2 | 5.1 | 0.55 | 0.17 | 0.15 | 0.22 | 0.04 |
| 2 | 8.5 | 4.4 | 0.49 | 0.16 | 0.13 | 0.18 | 0.04 |
| 2 | 5.5 | 3.9 | 0.43 | 0.13 | 0.12 | 0.17 | 0.03 |
| V. 14. | | | | | | | |
| 1 | 21. | 22.4 | 3.25 | 1.03 | 0.80 | 1.24 | 0.17 |
| 4 | 21.9 | 26. | 3.67 | 1.13 | 0.93 | 1.43 | 0.20 |
| 10 | 22.6 | 16.4 | 2.49 | 0.88 | 0.65 | 0.83 | 0.13 |
| 2 | 21.2 | 14.2 | 2.13 | 0.72 | 0.55 | 0.73 | 0.12 |
| 3 | 19.8 | 12.6 | 1.95 | 0.72 | 0.49 | 0.65 | 0.10 |
| 5 | 18.3 | 10.6 | 1.68 | 0.66 | 0.45 | 0.49 | 0.09 |
| 10 | 17.5 | 7.7 | 1.16 | 0.45 | 0.33 | 0.31 | 0.06 |
| 5 | 15.2 | 2.5 | 0.36 | 0.15 | 0.13 | 0.06 | 0.02 |
| V. 15. | | | | | | | |
| 1 | 13.3 | 17.4 | 2.37 | 0.80 | 0.64 | 0.83 | 0.11 |
| 2 | 20.5 | 20.7 | 2.82 | 0.95 | 0.77 | 0.99 | 0.14 |
| 2 | 26.5 | 16.5 | 2.24 | 0.74 | 0.61 | 0.78 | 0.11 |
| 2 | 27.8 | 16.4 | 2.22 | 0.73 | 0.60 | 0.77 | 0.11 |
| 3 | 23.8 | 12.7 | 1.74 | 0.58 | 0.47 | 0.61 | 0.09 |
| 3 | 23.4 | 8.3 | 1.22 | 0.46 | 0.31 | 0.39 | 0.05 |
| 4 | 17.5 | 7. | 1.03 | 0.39 | 0.26 | 0.33 | 0.05 |
| 7 | 15.3 | 4.8 | 0.65 | 0.23 | 0.20 | 0.19 | 0.03 |
| V. 16. | | | | | | | |
| 2 | 18 6 | 19.8 | No analyses of milk | | | | |
| 4 | 20.2 | 19.5 | | | | | |
| 1 | 29.5 | 17.4 | | | | | |
| 1 | 20.7 | 12.7 | | | | | |
| 1 | 29.2 | 12.7 | | | | | |
| 1 | 20.4 | 16.9 | | | | | |
| 2 | 18.1 | 11.8 | | | | | |
| 1 | 22.9 | 13.1 | | | | | |
| 1 | 18.8 | 10.5 | | | | | |
| 5 | 22. | 9.2 | | | | | |
| 5 | 19.6 | 7.2 | | | | | |
| 10 | 18. | 5.3 | | | | | |
| 3 | 15.3 | 3.6 | | | | | |
| 6 | 12.5 | 3.5 | | | | | |
| 3 | 11.5 | 2.8 | | | | | |
| 5 | 12.4 | 2.5 | | | | | |
| VI. 1. | | | | | | | |
| 6 | 36.6 | 31.6 | 3.76 | 1.08 | 0.86 | 1.58 | 0.22 |
| 5 | 31.7 | 26.6 | 3.23 | 0.88 | 0.79 | 1.41 | 0.18 |
| 4 | 29.7 | 22.1 | 2.70 | 0.77 | 0.65 | 1.14 | 0.16 |
| 2 | 28.2 | 17.7 | 2.13 | 0.65 | 0.55 | 0.77 | 0.14 |
| 8 | 19.3 | 8.3 | 0.84 | 0.26 | 0.25 | 0.25 | 0.08 |
| VI. 2. | | | | | | | |
| 0 | 26.6 | 31.4 | 3.71 | 1.05 | 0.86 | 1.60 | 0.22 |
| 0 | 25.1 | 21.5 | 2.52 | 0.70 | 0.58 | 1.13 | 0.15 |
| 5 | 22 9 | 16.7 | 1.96 | 0.57 | 0.49 | 0.76 | 0.12 |
| 5 | 21.4 | 14.1 | 1.67 | 0.49 | 0.41 | 0.67 | 0.10 |
| 9 | 20.1 | 9.4 | 1.08 | 0.33 | 0.28 | 0.41 | 0.06 |

| Weeks | Total dry matter in food | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VI. 2. | | | | | | | |
| 14 | 16.8 | 6.1 | 0.72 | 0.22 | 0.19 | 0.27 | 0.04 |
| VI. 3. | | | | | | | |
| 30 | 35.9 | 38.1 | 4.44 | 1.24 | 1.04 | 1.89 | 0.28 |
| 13 | 31.8 | 25.4 | 3.15 | 0.92 | 0.80 | 1.22 | 0.20 |
| 3 | 26.1 | 25.9 | 3.09 | 0.87 | 0.80 | 1.29 | 0.14 |
| 10 | 29.6 | 26. | 3.21 | 0.95 | 0.84 | 1.28 | 0.16 |
| 4 | 17.4 | 18.7 | 2.30 | 0.76 | 0.67 | 0.73 | 0.12 |
| 4 | 13.2 | 10.4 | 1.22 | 0.39 | 0.35 | 0.43 | 0.08 |
| VI. 4. | | | | | | | |
| 15 | 26.9 | 38.6 | 4.35 | 1.22 | 1.06 | 1.81 | 0.26 |
| 11 | 24.3 | 24.1 | 2.98 | 0.83 | 0.76 | 1.22 | 0.18 |
| 5 | 21.9 | 20.2 | 2.43 | 0.72 | 0.62 | 0.92 | 0.15 |
| 20 | 22.6 | 20.3 | 2.52 | 0.74 | 0.58 | 1.05 | 0.15 |
| 20 | 21.6 | 16.6 | 2.03 | 0.61 | 0.48 | 0.82 | 0.12 |
| VI. 5. | | | | | | | |
| 1 | 24.8 | 30.4 | 3.76 | 1.06 | 0.89 | 1.56 | 0.23 |
| 2 | 36. | 41.4 | 5.09 | 1.44 | 1.23 | 2.15 | 0.30 |
| 6 | 41.7 | 40.7 | 4.70 | 1.25 | 1.16 | 2.00 | 0.30 |
| 5 | 49.2 | 38.1 | 4.46 | 1.16 | 1.13 | 1.88 | 0.27 |
| 1 | 46.9 | 37.7 | 4.61 | 1.26 | 1.17 | 1.89 | 0.26 |
| 3 | 42.6 | 38. | 4.68 | 1.32 | 1.14 | 1.90 | 0.24 |
| 14 | 36. | 33. | 3.97 | 1.08 | 1.04 | 1.64 | 0.25 |
| 12 | 32.9 | 26.5 | 3.23 | 0.94 | 0.90 | 1.24 | 0.21 |
| 10 | 29.1 | 23.6 | 2.78 | 0.79 | 0.79 | 0.99 | 0.20 |
| 1 | 30.2 | 23.9 | 2.76 | 0.80 | 0.77 | 0.99 | 0.19 |
| 9 | 28.6 | 18.9 | 2.14 | 0.63 | 0.69 | 0.71 | 0.18 |
| 3 | 32.1 | 13.8 | 1.57 | 0.50 | 0.50 | 0.46 | 0.14 |
| 1 | 20.7 | 12.7 | 1.51 | 0.47 | 0.49 | 0.41 | 0.13 |
| 2 | 22.9 | 9.3 | 1.03 | 0.32 | 0.35 | 0.31 | 0.09 |
| 3 | 16.7 | 5. | 0.45 | 0.11 | 0.20 | 0.12 | 0.05 |
| 1 | 15.7 | 3.2 | 0.27 | 0.07 | 0.13 | 0.08 | 0.03 |
| VI. 6. | | | | | | | |
| 7 | 21.8 | 20.2 | 3.31 | 1.30 | 0.78 | 1.04 | 0.17 |
| 20 | 22.7 | 19.9 | 3.07 | 1.16 | 0.76 | 1.02 | 0.15 |
| 5 | 20.9 | 16.5 | 2.53 | 0.97 | 0.65 | 0.76 | 0.12 |
| 21 | 18.5 | 12.3 | 1.87 | 0.78 | 0.51 | 0.54 | 0.09 |
| 1 | 14. | 5.7 | 0.89 | 0.34 | 0.27 | 0.24 | 0.05 |
| VI. 7. | | | | | | | |
| 2 | 19.7 | 26.3 | 3.34 | 1.00 | 0.77 | 1.36 | 0.18 |
| 26 | 19.5 | 23.7 | 2.99 | 0.91 | 0.73 | 1.16 | 0.16 |
| 15 | 17.4 | 14.7 | 1.89 | 0.56 | 0.52 | 0.72 | 0.10 |
| 20 | 16.1 | 11.2 | 1.44 | 0.43 | 0.39 | 0.53 | 0.08 |
| 5 | 14.3 | 6.4 | 0.82 | 0.24 | 0.22 | 0.30 | 0.04 |
| 1 | 14.2 | 2.4 | 0.30 | 0.09 | 0.07 | 0.11 | 0.02 |
| VI. 8. | | | | | | | |
| 1 | 17.1 | 21. | 2.91 | 1.03 | 0.70 | 1.00 | 0.16 |
| 17 | 18.9 | 17.2 | 2.52 | 0.94 | 0.60 | 0.83 | 0.13 |
| 40 | 18. | 13.5 | 2.16 | 0.84 | 0 55 | 0.66 | 0.11 |
| 5 | 15.6 | 11.9 | 1.89 | 0.77 | 0.46 | 0.55 | 0.09 |
| 1 | 15.1 | 8.6 | 1.30 | 0.54 | 0.34 | 0.34 | 0.06 |
| 3 | 17.1 | 7.7 | 1.23 | 0.52 | 0.31 | 0.31 | 0.06 |
| 3 | 15.7 | 4.1 | 0.67 | 0.29 | 0.17 | 0.17 | 0.04 |

| Weeks | Total dry matter in food | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VI. 9. | | | | | | | |
| 1 | 14.7 | 16.9 | 2.30 | 0.73 | 0.56 | 0.81 | 0.12 |
| 1 | 7.5 | 32.7 | 4.56 | 1.44 | 1.14 | 1.64 | 0.24 |
| 9 | 10.1 | 30.9 | 4.28 | 1.49 | 1.07 | 1.51 | 0.23 |
| 11 | 16.7 | 24.8 | 3.48 | 1.26 | 0.86 | 1.23 | 0.19 |
| 10 | 22.2 | 18.4 | 2.61 | 0.93 | 0.67 | 0.89 | 0.13 |
| 10 | 20.5 | 13.9 | 2.04 | 0.74 | 0.53 | 0.65 | 0.11 |
| 30 | 17. | 10.5 | 1.50 | 0.55 | 0.40 | 0.48 | 0.08 |
| 38 | 15. | 7.7 | 1.15 | 0.43 | 0.31 | 0.35 | 0.08 |
| 8 | 14.2 | 5.3 | 0.80 | 0.30 | 0.22 | 0.22 | 0.04 |
| VI. 10. | | | | | | | |
| 3 | 16.7 | 16.6 | No analyses of milk made | | | | |
| 6 | 20.7 | 18.2 | | | | | |
| 9 | 20.1 | 12.9 | | | | | |
| 13 | 24.3 | 9.4 | | | | | |
| 19 | 20.8 | 6.8 | | | | | |
| 8 | 16. | 3.2 | | | | | |
| VI. 11. | | | | | | | |
| 1 | 21.9 | 27.1 | 3.81 | 1.26 | 0.96 | 1.34 | 0.21 |
| 6 | 24.3 | 25.8 | 3.48 | 1.14 | 0.81 | 1.31 | 0.19 |
| 10 | 23.4 | 17. | 2.27 | 0.75 | 0.59 | 0.79 | 0.13 |
| 12 | 22.1 | 13.1 | 1.93 | 0.71 | 0.49 | 0.63 | 0.10 |
| 5 | 19.1 | 10.3 | 1.58 | 0.60 | 0.40 | 0.51 | 0.08 |
| 5 | 16.8 | 9.6 | 1.47 | 0.55 | 0.36 | 0.49 | 0.07 |
| 5 | 15.6 | 8.5 | 1.36 | 0.53 | 0.33 | 0.45 | 0.05 |
| 5 | 14.6 | 7.9 | 1.26 | 0.49 | 0.31 | 0.40 | 0.06 |
| 10 | 11. | 7.2 | 1.07 | 0.42 | 0.27 | 0.33 | 0.06 |
| VI. 12. | | | | | | | |
| 1* | 14.2 | 29. | 4.41 | 1.51 | 1.03 | 1.66 | 0.23 |
| 1 | 20.1 | 26.9 | 4.09 | 1.40 | 0.98 | 1.53 | 0.21 |
| 2 | 26.4 | 28.9 | 4.34 | 1.49 | 1.01 | 1.62 | 0.21 |
| 10 | 25.8 | 25.2 | 3.82 | 1.38 | 0.89 | 1.36 | 0.19 |
| 10 | 23.6 | 20.7 | 3.22 | 1.21 | 0.76 | 1.06 | 0.17 |
| 10 | 21. | 18.5 | 2.78 | 1.07 | 0.70 | 0.91 | 0.14 |
| 10 | 19.4 | 12.3 | 1.87 | 0.71 | 0.50 | 0.55 | 0.10 |
| 7 | 16.3 | 7.4 | 1.13 | 0.40 | 0.31 | 0.33 | 0.06 |
| 15 | 14.8 | 7.5 | 1.18 | 0.45 | 0.32 | 0.35 | 0.06 |
| 5 | 13.7 | 6.3 | 1.01 | 0.41 | 0.27 | 0.30 | 0.05 |
| 8 | 9.9 | 2.1 | 0.34 | 0.14 | 0.09 | 0.10 | 0.02 |
| VI. 13. | | | | | | | |
| 1 | 19.4 | 16.3 | 2.14 | 0.72 | 0.51 | 0.80 | 0.11 |
| 3 | 21.4 | 22.8 | 3.05 | 1.04 | 0.72 | 1.12 | 0.16 |
| 5 | 22.9 | 19.4 | 2.66 | 0.98 | 0.63 | 0.90 | 0.14 |
| 12 | 21.9 | 15.4 | 2.21 | 0.78 | 0.57 | 0.75 | 0.12 |
| 10 | 22.9 | 13.1 | 2.08 | 0.81 | 0.53 | 0.65 | 0.10 |
| 5 | 19.3 | 10.5 | 1.73 | 0.68 | 0.44 | 0.53 | 0.08 |
| 16 | 17.7 | 9.2 | 1.50 | 0.63 | 0.37 | 0.45 | 0.07 |
| 7 | 13.7 | 5.5 | 0.85 | 0.30 | 0.22 | 0.28 | 0.05 |
| VI. 14. | | | | | | | |
| 1* | 18.6 | 33.8 | 4.83 | 1.60 | 1.19 | 1.73 | 0.23 |
| 2 | 24.4 | 30.9 | 4.41 | 1.48 | 1.05 | 1.67 | 0.24 |
| 5 | 23.7 | 28.6 | 4.04 | 1.42 | 0.94 | 1.45 | 0.22 |
| VI. 14. | | | | | | | |
| 5 | 24. | 22.7 | 3.25 | 1.16 | 0.77 | 1.14 | 0.18 |
| 5 | 22.7 | 17.8 | 2.53 | 0.92 | 0.62 | 0.82 | 0.14 |
| 17 | 19.7 | 11.8 | 1.79 | 0.68 | 0.48 | 0.54 | 0.09 |
| 5 | 16.6 | 7.9 | 1.28 | 0.51 | 0.34 | 0.36 | 0.07 |
| 11 | 14.3 | 5.5 | 0.92 | 0.38 | 0.24 | 0.26 | 0.06 |
| 3 | 11.5 | 4.8 | 0.79 | 0.33 | 0.19 | 0.22 | 0.04 |
| 8 | 9.5 | 3.1 | 0.52 | 0.21 | 0.14 | 0.17 | 0.03 |
| VI. 15. | | | | | | | |
| 3 | 24. | 27.9 | 4.21 | 1.43 | 1.05 | 1.50 | 0.23 |
| 10 | 24.4 | 25.8 | 3.84 | 1.33 | 0.90 | 1.41 | 0.21 |
| 10 | 22.9 | 21.3 | 3.15 | 1.11 | 0.77 | 1.12 | 0.17 |
| 17 | 22.8 | 16. | 2.49 | 0.85 | 0.64 | 0.83 | 0.13 |
| 10 | 20.7 | 12. | 1.85 | 0.68 | 0.49 | 0.59 | 0.10 |
| 9 | 18.2 | 11.1 | 1.72 | 0.64 | 0.45 | 0.54 | 0.09 |
| 12 | 11.9 | 5. | 0.78 | 0.31 | 0.18 | 0.25 | 0.04 |
| VII. 1. | | | | | | | |
| 4 | 23. | 36.4 | 4.37 | 1.26 | 1.00 | 1.87 | 0.25 |
| 4 | 32.1 | 33.8 | 3.96 | 1.12 | 0.91 | 1.68 | 0.23 |
| 11 | 32.3 | 29.6 | 3.55 | 1.01 | 0.82 | 1.51 | 0.21 |
| VII. 2. | | | | | | | |
| 1. | 11.4 | 15.7 | 2.34 | 0.89 | 0.51 | 0.80 | 0.10 |
| 1 | 10. | 22. | 3.27 | 1.24 | 0.71 | 1.14 | 0.13 |
| 1 | 7.8 | 24.3 | 3.53 | 1.33 | 0.76 | 1.23 | 0.16 |
| 1 | 15.9 | 24.6 | 3.47 | 1.30 | 0.74 | 1.23 | 0.16 |
| 2 | 20.8 | 27.5 | 3.77 | 1.39 | 0.87 | 1.39 | 0.17 |
| 10 | 24.2 | 25. | 3.50 | 1.26 | 0.88 | 1.20 | 0.17 |
| 2 | 25.6 | 20.3 | 3.15 | 1.24 | 0.80 | 0.93 | 0.15 |
| 2 | 30.3 | 17.7 | 2.70 | 1.03 | 0.69 | 0.82 | 0.13 |
| VII. 3. | | | | | | | |
| 4 | 19.3 | 24.4 | 3.31 | 1.12 | 0.84 | 1.14 | 0.17 |
| 1 | 22.4 | 24. | 3.10 | 0.90 | 0.84 | 1.26 | 0.16 |
| 9 | 24.8 | 18.9 | 2.55 | 0.84 | 0.65 | 0.93 | 0.13 |
| 6 | 23.8 | 14.4 | 2.21 | 0.81 | 0.56 | 0.73 | 0.10 |
| 6 | 19.1 | 10.7 | 1.70 | 0.64 | 0.47 | 0.53 | 0.07 |
| 3 | 13.8 | 2.9 | 0.49 | 0.19 | 0.13 | 0.14 | 0.02 |
| VII. 4. | | | | | | | |
| 1† | 10.4 | 23.1 | No analyses of milk | | | | |
| 6 | 20.8 | 21.2 | | | | | |
| 2 | 23.9 | 16.1 | | | | | |
| 2 | 23.5 | 16.3 | | | | | |
| 4 | 22.6 | 15.4 | | | | | |
| 6 | 25.7 | 13.8 | | | | | |
| VIII. 1. | | | | | | | |
| 4 | 32.4 | 26.4 | 3.25 | 0.90 | 0.79 | 1.35 | 0.18 |
| 8 | 32.9 | 25.9 | 3.19 | 0.91 | 0.81 | 1.29 | 0.18 |
| 3 | 30.8 | 25. | 3.13 | 0.92 | 0.81 | 1.26 | 0.18 |
| 3 | 30.1 | 23.8 | 2.99 | 0.87 | 0.78 | 1.20 | 0.16 |
| 12 | 27.3 | 19.1 | 2.42 | 0.72 | 0.66 | 0.88 | 0.14 |
| 2 | 25.1 | 9.8 | 1.30 | 0.42 | 0.39 | 0.44 | 0.09 |
| 1 | 19.5 | 4.7 | 0.60 | 0.18 | 0.17 | 0.20 | 0.04 |
| 6 | 17.2 | | | Dry | | | |

*Three days only. †Six days only.

| Weeks | Total dry matter in food | Milk | Total solids | Fat | Casein and albumin | Milk sugar | Ash |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| VIII. 2. | | | | | | | |
| 5 | 28.5 | 30.4 | 3.56 | 0.97 | 0.85 | 1.55 | 0.21 |
| 13 | 27.6 | 28.3 | 3.30 | 0.89 | 0.84 | 1.39 | 0.19 |
| 13 | 26.7 | 19.8 | 2.41 | 0.69 | 0.67 | 0.91 | 0.14 |
| 3 | 21.7 | 4.2 | 0.53 | 0.17 | 0.16 | 0.16 | 0.03 |
| 1 | 21.1 | | | Dry | | | |
| 4 | 18.5 | | | Dry | | | |
| VIII. 3. | | | | | | | |
| 9 | 20.4 | 13.9 | 1.68 | 0.49 | 0.43 | 0.66 | 0.10 |
| 1 | 19.1 | 12.3 | 1.54 | 0.47 | 0.40 | 0.57 | 0.09 |
| 1 | 15.9 | 8. | 1.01 | 0.31 | 0.27 | 0.39 | 0.06 |
| 16 | 18.5 | 10.5 | 1.28 | 0.37 | 0.35 | 0.50 | 0.08 |
| 5 | 17.8 | 4.9 | 0.68 | 0.21 | 0.26 | 0.20 | 0.04 |
| 2 | 18. | 1.6 | 0.24 | 0.07 | 0.09 | 0.06 | 0.01 |
| 6 | 16.9 | | | Dry | | | |
| VIII. 4. | | | | | | | |
| 3 | 20.3 | 17. | 1.91 | 0.52 | 0.43 | 0.84 | 0.12 |
| 5 | 19.2 | 15.4 | 1.73 | 0.49 | 0.40 | 0.77 | 0.11 |
| 3 | 20.1 | 16.5 | 1.92 | 0.56 | 0.46 | 0.81 | 0.11 |
| 3 | 18.5 | 16.8 | 1.92 | 0.53 | 0.46 | 0.83 | 0.11 |
| 18 | 17.8 | 10.6 | 1.26 | 0.36 | 0.31 | 0.48 | 0.08 |
| 7 | 17.8 | | | Dry | | | |
| VIII. 5. | | | | | | | |
| 5 | 27.8 | 19.5 | 2.34 | 0.67 | 0.65 | 0.88 | 0.14 |
| 8 | 24.9 | 10.6 | 1.25 | 0.37 | 0.35 | 0.46 | 0.09 |
| 3 | 22.3 | 5.5 | 0.70 | 0.21 | 0.21 | 0.23 | 0.05 |
| 13 | 22.2 | | | Dry | | | |
| 3 | 19.9 | | | Dry | | | |
| 8 | 17.5 | | | Dry | | | |
| VIII. 6. | | | | | | | |
| 6 | 22.8 | 14.1 | 2.13 | 0.76 | 0.58 | 0.66 | 0.10 |
| 12 | 21.1 | 12.5 | 1.81 | 0.65 | 0.49 | 0.56 | 0.10 |
| 6 | 19.7 | 6.9 | 1.00 | 0.35 | 0.31 | 0.28 | 0.06 |
| 2 | 19.7 | | | Dry | | | |
| VIII. 6. | | | | | | | |
| 14 | 17.2 | | | Dry | | | |
| VIII. 7. | | | | | | | |
| 15 | 22.8 | 21. | 2.97 | 1.06 | 0.74 | 1.04 | 0.15 |
| 10 | 21.9 | 15. | 2.11 | 0.78 | 0.58 | 0.68 | 0.11 |
| 5 | 19.9 | 6.7 | 0.99 | 0.36 | 0.30 | 0.29 | 0.05 |
| 6 | 16.1 | | | Dry | | | |
| 3 | 16.8 | | | Dry | | | |
| VIII. 8. | | | | | | | |
| 9 | 27.8 | 18.4 | 2.93 | 1.11 | 0.79 | 0.89 | 0.13 |
| 4 | 25.2 | 15.1 | 2.44 | 0.93 | 0.66 | 0.75 | 0.12 |
| 6 | 24.3 | 14. | 2.33 | 0.91 | 0.60 | 0.67 | 0.10 |
| 8 | 22.6 | 11. | 1.84 | 0.71 | 0.53 | 0.49 | 0.09 |
| 4 | 20.8 | 6.8 | 1.12 | 0.41 | 0.36 | 0.26 | 0.06 |
| 1 | 17.5 | 6.5 | 0.97 | 0.32 | 0.29 | 0.18 | 0.05 |
| 2 | 15.4 | 2.8 | 0.42 | 0.14 | 0.14 | 0.09 | 0.03 |
| 5 | 15.4 | | | Dry | | | |
| VIII. 9. | | | | | | | |
| 17 | 29. | 18.5 | 2.98 | 1.14 | 0.80 | 0.89 | 0.14 |
| 2 | 26.8 | 15.6 | 2.56 | 0.98 | 0.71 | 0.72 | 0.12 |
| 2 | 25.1 | 12.5 | 2.05 | 0.81 | 0.59 | 0.60 | 0.10 |
| 6 | 24.2 | 8.6 | 1.54 | 0.60 | 0.40 | 0.45 | 0.07 |
| 2 | 22.5 | 4.9 | 0.89 | 0.35 | 0.23 | 0.25 | 0.04 |
| 1 | 17.1 | 1.4 | 0.26 | 0.10 | 0.06 | 0.07 | 0.03 |
| 5 | 17.1 | | | Dry | | | |
| 4 | 14.3 | | | Dry | | | |
| VIII. 10. | | | | | | | |
| 13 | 22.5 | 15.9 | 2.48 | 0.96 | 0.68 | 0.73 | 0.11 |
| 9 | 21. | 11.5 | 1.83 | 0.70 | 0.54 | 0.52 | 0.09 |
| 1 | 19.4 | 2.8 | 0.59 | 0.17 | 0.17 | 0.16 | 0.03 |
| 8 | 19.4 | | | Dry | | | |
| 1 | 17.3 | | | Dry | | | |
| 5 | 14.6 | | | Dry | | | |
| 2 | 16.1 | | | Dry | | | |

JULY, 1922 BULLETIN 227

University of Vermont and State Agricultural College

# Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# MARKETING VERMONT MAPLE-SAP PRODUCTS

*By* A. W. McKAY

*Specialist in Market Extension, Bureau of Markets and Crop Estimates,*
*United States Department of Agriculture, Washington, D. C.*

1791

**[With the Cooperation of the United States Department of Agriculture, Bureau of Markets and Crop Estimates, and the Vermont Agricultural Extension Service]**

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# BULLETIN 227: MARKETING VERMONT MAPLE-SAP PRODUCTS[1]

BY A. W. McKAY

The Vermont Maple Sugar Makers' Association, at its 28th annual meeting in January, 1921, appointed a committee to study the marketing of maple products. It held several conferences with Vermont Extension Service officials and, as a result, representatives of the Bureau of Markets and Crop Estimates of the United States Department of Agriculture spent about two months in Vermont and vicinity last fall studying the entire proposition. The author of this bulletin, Mr. Andrew W. McKay, who made the major part of the investigation, presented his findings at the 29th annual meeting of the Association in January, 1922, and at several times was in council with its committee. As a result, and largely based upon the presentation made in this bulletin, the Vermont Maple Products Cooperative Exchange, Inc., has been formed and is now functioning.

Several of the officials of the Vermont Extension Service were of much assistance to Mr. McKay in an advisory way.

The Station appreciates and acknowledges the courtesy of the officials of the United States Department of Agriculture, Bureau of Markets and Crop Estimates, in permitting it to publish this valuable material.

J. L. HILLS, Director.

## INTRODUCTION

The demand for pure maple syrup and maple sugar is gradually diminishing. The new generation of consumers is reasonably well satisfied with the various forms of blended or compounded syrups now on the market. The demand for pure maple syrup, at the present time, is confined largely to residents, or former residents of maple-sap producing sections. Consumers of this class have been accustomed to maple-sap products since childhood, and in consequence they prefer a pure maple product. However, if pure maple syrup or sugar of good quality can not be obtained at a price which they consider reasonable, they will often accept a high class blended syrup with maple flavor.

The large mass of the people, especially those foreign born, or of foreign-born parentage, have had no opportunity to cultivate a taste for maple-sap products in childhood. Consequently a distinctive maple flavor makes no special appeal to them. They are interested in quality, considered apart from any particular flavor, but most of all in price. They will not buy pure maple syrup at a price appreciably greater than that asked for corn, cane, or blended syrups.

As a result of this condition, a large proportion of the output of maple-sap products is being sold each year for flavoring purposes. Prices paid for maple sugar and syrup used for flavoring have generally been below what the producers consider a fair return for their labor, and the capital invested. The Vermont producers, in common with those of other states, believe that the widespread use of maple-sap products in the manufacture of blended syrups is detrimental to the best interests of the industry on account of the fact that it makes possible the production of a product which is in direct competition with pure maple syrup. Accordingly, they have recently organized a cooperative marketing association[1] for the purpose of developing markets and stimulating the demand for pure maple syrup and sugar.

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[1] The survey on which the section regarding retailing methods is based (pages 32-35) was made by R. H. Elsworth, Bureau of Markets and Crop Estimates, United States Department of Agriculture.

The purpose of this bulletin is to discuss the problems and difficulties involved in this undertaking, and the methods which seem most likely to lead to their successful solution.

## EARLY HISTORY

There is very little information with regard to the beginnings of the maple-sugar industry in Vermont. Some historians report that sugar was made by the Indians from the sap of the sugar maple before the arrival of the white man. However, it is extremely doubtful if the Indians actually reduced the sap to the form of crystallized sugar. In this connection a Vermont writer[2] states:

> **"Moreover, when the white race entered Canada, sugar was quoted on the European markets at prices around fifteen dollars a pound. The main object of the French people in coming to Canada was to trade with the Indians. Now, had maple sugar been known among the Indians, it seems strange that it was not enumerated among the articles of trade with those people. Instead, there is no mention made of it in any of the writings of the early explorers for upwards of one hundred years after trade relations had become established."**

According to the same writer, the first mention of maple sugar in New England was in 1720, when a short description of the process of manufacture was published in the "Philosophical Transactions of the Royal Society." Undoubtedly, maple sugar at that time was produced only for home use. By 1790, however, it was locally at least an article of commerce. In 1792 there was published at Philadelphia an account of the sugar-maple tree of the United States.[3] The material contained in this publication was originally prepared as a letter to Thomas Jefferson, then Secretary of State, and was read at a meeting of the American Philosophical Society, August 19, 1791. The author quotes the following from the *Albany Gazette,* which shows that considerable quantities of maple sugar were then sold in certain sections.

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[1] The Vermont Maple Products Cooperative Exchange, Inc., was organized in March, 1922, with headquarters at Essex Junction, Vt. In New York State, the Maple Producers' Cooperative Association was recently organized, with headquarters at Syracuse.

[2] Ormsbee, C. O.: Vt. Sugar Makers' Assoc., Rpt. 24, pp. 21-22 (1917).

[3] An account of Sugar-Maple Tree of the United States" by Benjamin Rush, M. D. R. Aitken & Son, Philadelphia, 1792.

**"Received Cooper's Town, April 30th, 1790, of William Cooper, fifteen pounds, for six hundred and forty pounds of sugar made with my own hands, without any assistance, in less than four weeks, besides attending to the other business of my farm, as providing fire wood, taking care of the cattle, etc. John Nicholls, Witness R. Smith."**

At that time the author estimated it was possible to produce 135,000,000 pounds of maple sugar annually in the United States valued "at 6/90 of a dollar per pound," of which $8,000,000 worth could be consumed at home, and $1,000,000 worth exported. It is interesting to note also that, although the equipment described is very crude, many modern practices in gathering and processing the sap were recommended by Dr. Rush over 130 years ago.

However, according to Ormsbee,[1] improvement in methods of manufacture were not adopted before 1825. From 1840 to 1850 there were many improvements made in the type of implements used. Many, in fact nearly all, of these improvements may be traced to the inventive genius of one man, Owen Cummings, who was born at Montpelier, Vermont, in 1801. The pan evaporator with a corrugated bottom, probably the most important single advance in farm processing equipment, was developed by Cummings between 1850 and 1860.

## PRODUCTION IN VERMONT

The average annual production of Vermont maple products has remained fairly constant during the past 60 years. However, although the number of trees tapped has changed very little, production may vary greatly from year to year. It is impossible to determine in advance of the sap flow whether the yield will be great or small. The yield is mainly dependent upon weather conditions, although widespread insect injury has been a limiting factor in the past.

The flow of sap begins as a rule late in March. At this time the temperature rises a few degrees above the freezing point during the day, and falls below freezing at night. The flow is not constant, but is divided into periods known as "runs" whose length and periodicity are dependent upon temperature conditions. There may be only one or two "good sap days" during the season, or there may be four or five "runs," each extending over a period of two or three days. Cold nights followed by warm cloudy days are ideal. If the temperature remains constant, either above or below freezing, the sap flow ceases.[2]

The area of greatest production in Vermont is found in the four northern counties, Franklin, Orleans, Caledonia, and Lamoille. Wash-

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[1] Loc cit., pp. 26-27.

[2] For a very full discussion of the problems of the sap pressure and flow, see Vt. Sta. Bul. 103, pages 56-115 (1903).

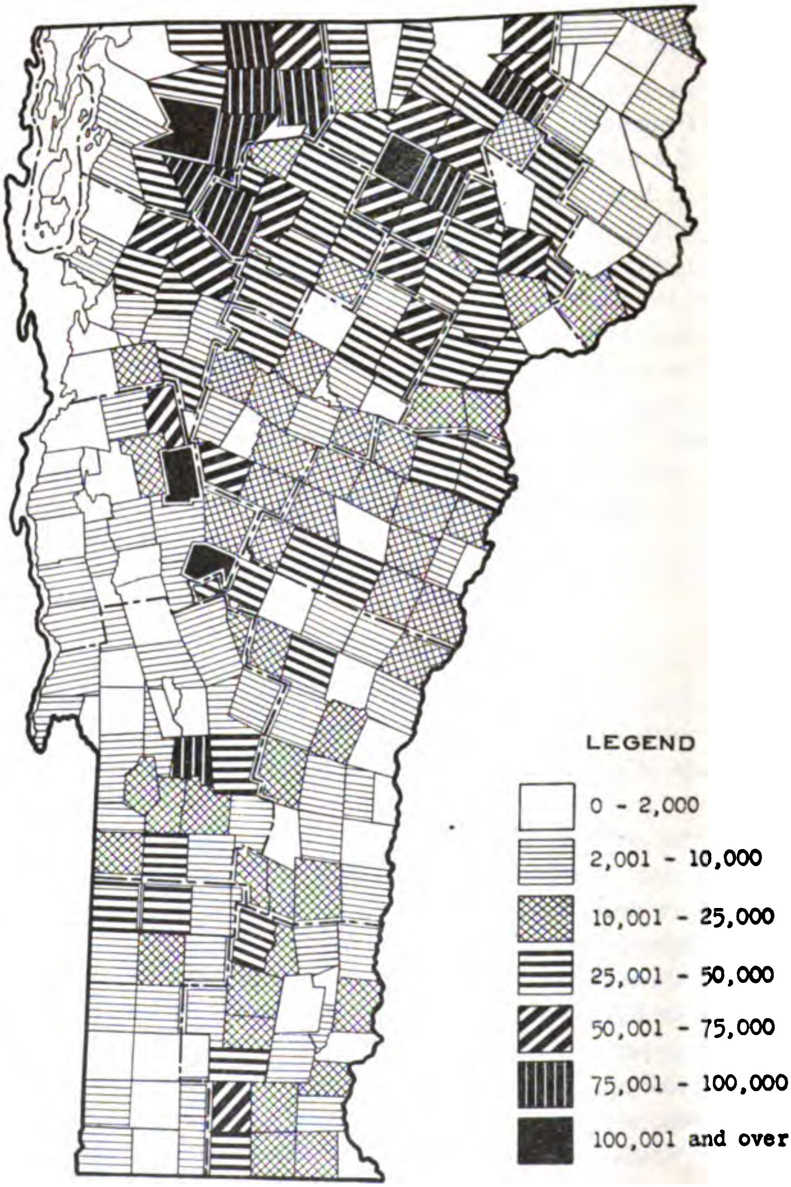

FIGURE 1. Map showing the number of trees tapped in each Vermont town, as reported by the 1917 lister's census. Towns where less than 2,000 trees were tapped are unshaded.

ington County, also, is a heavy producer of maple syrup and sugar. In general, production is heaviest in the northern part of the State, and it also follows the line of the Green Mountains, which curve from the western border in the south towards the central portion in the north.

The accompanying map shows the number of trees tapped in each town during the season of 1917, according to the lister's census, compiled by the Secretary of State for Vermont. The location of the centers of heaviest production may be easily determined by reference to this map. The total number of trees tapped varies from 5,500,000 to 6,000,000. In 1919, Vermont produced 6,251,734 pounds of maple sugar, and 631,924 gallons of syrup. In terms of sugar, this is equivalent to 11,307,316 pounds, or, as syrup, to 1,413,391 gallons. The production for 1919 may be considered as typical of the average.

Two pounds of sugar per tree is generally accepted as the average yield. The census figures[1] substantiate this claim. For 1909, the yield per tree was 1.97 pounds of sugar, and in 1919, the yield was 1.89 pounds. In terms of syrup this approximates one-fourth gallon.

## PRODUCTION IN THE UNITED STATES

In 1909, the 13 states which are represented in table 2 produced 98.4 percent of the maple syrup and 99 percent of the maple sugar of the United States,[2] according to the reports of the Bureau of Crop Estimates. The total production of these states expressed in terms of sugar has varied from 25,000,000 to over 50,000,000 pounds during the past five years. The average yield has been from 35,000,000 to 40,000,000 pounds. The Canadian production is placed by Canadian manufacturers at approximately 15,000,000 to 20,000,000 pounds annually, so that the average annual production for the American continent is between 50,000,000 and 60,000,000 pounds of sugar.

In 1860, and previously, a considerable quantity of sugar was produced in the States of North Carolina, Tennessee, Kentucky, Missouri, and Virginia. In 1860 these states produced the equivalent of 4,538,550 pounds of sugar. By 1909, however, the output of the five states had dropped to 233,014 pounds of sugar, or its equivalent in syrup.

The accompanying map represents by counties the number of trees tapped in each of the most important producing states. Table 3 gives in addition the production of each state in terms of sugar for 1919 and table 4 shows imports of maple syrup and sugar from 1914 to 1920.

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[1] Agricultural Census, Vermont, 1920.

[2] U. S. Dept. Agr. Yearbook, 1920, p. 689.

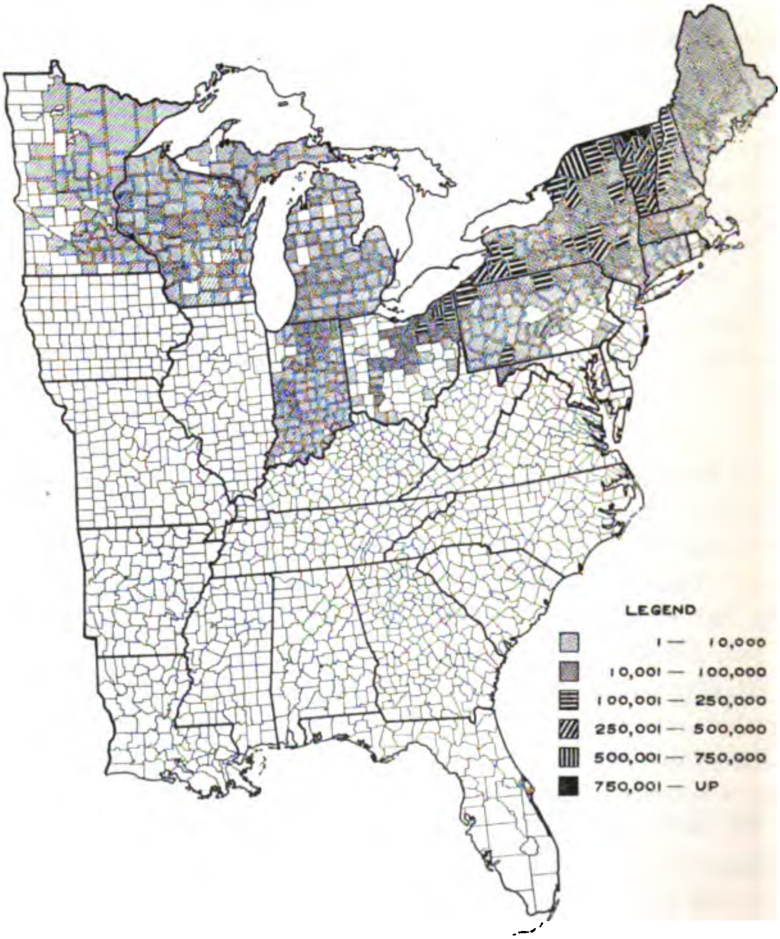

FIGURE 2. Number of maple trees tapped by counties in the principal producing States, 1919, United States census reports.

## PROCESSING

The processing of maple products may be performed entirely upon the farm, or it may be performed on the farm and at a manufacturing plant. The sap as drawn from the tree must be reduced by the producer to the form of syrup. Farm processing can not be avoided on account of the necessity for handling the sap quickly to avoid fermentation and infection by micro-organisms.[1] Furthermore, it is not economical to transport sap to a central plant on account of its great bulk as compared with the finished product. Approximately 30 gallons of sap are required to produce one gallon of syrup.

The producer, therefore, evaporates his sap theoretically to a standard density. The proper density may be determined: (*a*) By the weight of the cool syrup, which should be 11 pounds per gallon at 60° F.; (*b*) by the Baumé hygrometer—syrup of standard density will test 36° on the Baumé scale at 60° F.; or (*c*) by the use of a thermometer.[2] The last is the only practical method for determining the density of the syrup before processing is completed, and is generally followed by the Vermont producers. The boiling point of syrup concentrated to a density of 11 pounds per gallon is 219° F. at sea-level, or seven degrees higher than the boiling point of water. To determine the boiling point of syrup of standard density at any altitude, therefore, it is only necessary to know the boiling point of water at that altitude, and to add seven degrees to this figure.

In so far as density is concerned, the rules for the manufacture of maple syrup are extremely simple. To obtain desirable color and flavor, it is necessary to concentrate the sap as soon as possible after drawing, and to observe rigid rules of cleanliness. Prompt processing and cleanliness make up the greater part of the "trade secrets" of those farmers who produce fancy grades. However, the flavor and color obtained vary somewhat during the season, and from season to season.

A considerable percentage, between 15 and 20 percent, of the syrup produced in Vermont goes directly from the farms to the consumers without further processing. However, the greater part of the product now goes to the manufacturing plants in the form of syrup. It is shipped to them almost entirely in 55-gallon steel drums (a 30-gallon size is gaining in popularity) and has presumably been concentrated to standard density on the farm.

Formerly large quantities of sugar were put up in butter tubs, and other containers of similar form, and shipped to manufacturers or blenders. Owing to irregularities of grade and to the actual presence of foreign matter in tub sugar, dealers now discourage its production.

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[1] In this connection see the very full discussions of the micro-biology of the maple sap flow in Vt. Sta. Buls. 151 (1910) and 167 (1912).

[2] In this connection see Vt. Sta. Bul. 26, pp. 55-59 (1891); Rpt. 5, pp. 20-29, 160-162 (1891); U. S. Dept. Agr., Farmers' Bul. 516 (1918.

To understand fully the relations of the dealer-manufacturer to the producer, it must be borne in mind that he is not, except in an insignificant degree, a manufacturer of pure maple syrup or sugar for domestic use. The dealers are either blenders, manufacturing a syrup flavored with maple, or they manufacture from the syrup or sugar they receive block sugar to be used by blenders, tobacco manufacturers or manufacturers of confectionery. Almost without exception, therefore, syrup received from the farmers is mixed and reboiled by the dealers in order to put it in a form that can be readily marketed. In addition, much syrup received at the plants is below standard density and must be reboiled within a short time to prevent fermentation.

## LOCAL TRANSPORTATION

The present rates for syrup in less than car lots, in "bulk in barrels," range from 19½ cents per hundredweight for distances of five miles or less to 36 cents per hundredweight for a distance of 95 to 100 miles, and 46½ cents per hundredweight for a distance of 190 to 200 miles. The dealers estimate the average local freight at five cents per gallon. The rate on empty drums is 19½ cents per hundredweight for a distance of five miles or less, 36 cents per hundredweight for a distance of 95 to 100 miles, and 46½ cents per hundredweight for a distance of 190 to 200 miles. Fifty miles is approximately the average distance which syrup is shipped to the manufacturing plants. The total cost of shipping a drum of syrup this distance, including the cost of forwarding the empty drum to the producer, is $2.52 or 4.6 cents per gallon, the weight of the syrup being considered 605 pounds and that of the container 110 pounds. The dealers' figure of 5 cents per gallon, therefore, is sufficiently accurate for all practical purposes.

The drums in which the syrup is transported are shipped to the local buyer in advance of the season and are distributed by him to the farmers. These drums are made of steel and are similar to gasoline drums. They are the property of the manufacturing plant, and are loaned without charge, provided the syrup is sold to the manufacturer.

The cost of local transportation must be considered in locating a manufacturing plant. The establishment of several cooperative manufacturing plants throughout the State has been advocated in order to reduce transportation costs. However, several other factors must be considered, and it seems conclusive that from the point of view of efficiency, economy of operation, and standardization of the product, one large plant will give better results than three or four smaller units. The factors involved in plant location, therefore, are first of all, a desirable site; secondly, good railroad facilities; and, thirdly, a location as near to the center of production as possible.

The center of production, for the last few seasons at least, is located at some point in the town of Morristown, Lamoille County. Theoretically, therefore, the village of Morrisville, in this town, would be the most desirable location for a processing plant. However, Morrisville is on a branch railroad and does not have direct connections with the large producing sections. The east and west line which divides the state into two areas of equal production passes through Burlington and Essex Junction on the west, and a few miles north of St. Johnsbury on the eastern border of the state. It is interesting to note that the largest syrup plants are located in these three cities. St. Johnsbury, on the Boston and Maine Railroad, has direct connection with the large producing centers of Orleans County, while Burlington, located on the Rutland and Central Vermont Railways, and Essex Junction, on the main line of the Central Vermont Railway, have easy access to the Franklin County producing districts. Franklin and Orleans Counties, as will be seen by reference to figure 1, are the largest counties in point of production. Freight on out of state shipments need not be considered in locating a central plant.[1]

## EQUIPMENT

The equipment used on the farm consists of a number of tin or galvanized iron sap buckets, usually with covers, approximately one for each tree tapped, although two or more may be placed on the largest trees,; two or three gathering pails; spouts or "spiles"; a gathering tank; a sap-storage tank; and the evaporator with its supporting brick arch and fire box, flue and chimney. At present prices, the cost of this equipment for a thousand-tree bush, which is about the average size, will be $1 per tree, aside from the cost of the sugar house.

The evaporator consists of a flat pan of heavy tin ranging in size from 36 inches x 72 inches to 6 feet x 16 feet and with a "daylight boiling capacity" sufficient to reduce the sap of from 200 to 3,000 trees. There are several makes of evaporators on the market, but all of them are very similar in general design. The evaporator pan is supported by a metal arch lined with fire brick which serves as a fire box, and provides for the distribution of heat to all parts of the evaporator in the proportion required. The pan is divided into six or seven compartments. The production of good syrup requires rapid evaporation, especially in the early stages. The first compartment which the sap enters has deep "flues," or corrugations in the bottom. These are about eight inches deep and one-half inch wide. The flues divide the sap into thin sheets, and as this compartment is located over the hottest part of the fire, evaporation is very rapid. The concentrated sap passes automatically from one compartment to the next until it reaches the last compartment, or the syrup "draw-off pan."

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[1] See table 10 in Appendix.

In the central plants, syrup is boiled in copper kettles, equipped with steam coils. The nature of the business conducted, and the quantity of syrup or sugar handled determines the kind and amount of machinery employed in the manufacturing plants. In addition to the steam boiling kettles, all the larger plants have storage and mixing tanks from which the syrup may be pumped to the kettles. If engaged in preparing pure or blended syrup for market, they also are equipped with automatic filling machines, capping or canning machines and labelling machines.

The largest manufacturing plant in Vermont is equipped principally for the manufacture of block sugar. The syrup is received on the first floor and the drums are emptied into two 10,000-gallon steel storage tanks in the basement. From these tanks, equipped with agitators, the syrup is pumped to a tank on the fourth floor. From this it flows by gravity to large copper steam kettles on the third floor. This syrup is heated to a temperature of 256° to 260° F., the purpose being to secure an extremely hard sugar. From the kettles the syrup runs by gravity to large "graining tanks" on the second floor. It is stirred in these tanks by an elongated paddle wheel for about half an hour. At the end of this time it has cooled considerably, but will still flow freely. It is drawn from the tanks directly into the boxes in which it is shipped. These boxes are a little smaller than an ordinary soap box and are lined on the bottom and on the sides with heavy oiled paper. These boxes pass in front of the "graining tanks" on the roller conveyors, and after they are filled are carried by a moving belt into the next room. Here they are diverted on a series of roller conveyors running across the room. They stand on these conveyors for about three hours, or until the sugar is completely cooled. The covers are then nailed on the boxes. The boxes pass over a scale which is part of the roller conveyor system, and the net weight is marked on each.

They then roll down a circular conveyor to the first floor and over movable conveyors to the car.

## LABOR

The greater proportion of Vermont maple syrup is produced by the labor of the farmer and his family, or by family labor assisted by one hired man. In only a few cases is hired labor employed exclusively. It is a rather general practice, however, for the farmer to employ the hired help he requires for his spring and summer work at the beginning of the maple-sap season. The farmer's cash expenditure for labor, therefore, is usually not a large item. Although his own labor and that of his family should command a fair return for the sap season, he is in many instances influenced in his decision to tap by the fact that he is able to employ otherwise idle labor.

## COST OF PRODUCTION

Two attempts have been made to determine production costs.

The first was made by C. J. Frink, a graduate of the College of Agriculture of the University of Vermont in the class of 1913, in connection with senior thesis work.[1] Data were secured during the spring of 1912 from 52 representative sugar makers in Franklin, Lamoille, Orleans and Orange Counties and especially exact data from nine operators in 1913. Of course the results then secured have little bearing now except in a historical way. No one today can make sugar for 11 cents or syrup for 86 cents, the average figures found by Frink.

In 1921, a second study was made by M. P. Rasmussen, then farm management demonstrator in the Extension Service.[2] Records were kept by 67 farmers, and 60 of the reports received were summarized. The figures published show that it cost these 60 farmers, on the average, $1.52 per gallon to produce maple syrup.

| Item | Cost per gallon | Percent of cost |
|---|---|---|
| Human labor | $0.56 | 36% |
| Horse labor | .16 | 10 |
| Wood (fuel) | .25 | 16 |
| Repairs | .01 | 1 |
| Depreciation on equipment | .19 | 12 |
| Interest on average investment in equipment | .20 | 13 |
| Interest on average investment in sugar bush | .06 | 5 |
| Total gross cost per gallon | $1.54 | 100% |
| Credits for pasture, etc., per gallon | .02 | |
| Net cost per gallon | $1.52 | |

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[1] Vt. Sta. Bul. 203, pp. 17-24 (1917).

[2] Vt. Ext. Serv., "The Cost of Producing Maple Syrup and Sugar on 60 Vermont Farms" (Progress Report 1921; mimeographed form).

The report shows that on five farms syrup was made for less than $1.00 per gallon, that on 13 the cost was between $1.00 and $1.25 per gallon, that it cost 10 producers from $2.01 to $2.50 per gallon to produce sugar, and that on two farms syrup was made at a cost in excess of $2.50 per gallon. According to the report, the cost of production was directly affected by (*a*) the size of the sugar bush; (*b*) efficiency in the use of labor; and (*c*) the yield per tree. The average cost for 14 orchards of 1,000 to 1,500 trees each (average group 1,207) was $1.17 per gallon, while 15 orchards of 451 to 750 trees each (average of group 605) show an average cost of $1.61 per gallon. The number of hours of man-labor required to produce 100 gallons of syrup ranged from as low as 71 hours to as high—in a single instance—as 416 hours, a preposterous figure. This factor naturally greatly influences the cost of production, as does also the yield per tree. The average yield for the state in 1921 was considerably below normal, and the average for the 60 farms represented was 1.7 pounds of sugar or 0.21 gallons of syrup per tree. Eighteen farmers reported an average yield for the group of 1.2 pounds per tree, and the average cost of production for this group was 26 cents per pound, or about $2.08 per gallon of syrup. Another group of 23 farms reported an average production of 2.3 pounds of sugar per tree, and an average production cost of 16 cents per pound, or approximately $1.27 per gallon of syrup. The average number of trees per orchard on the farms represented in this report was 915, and the investment in equipment reported was 86 cents per tree.

The above figures were obtained during a year of high labor costs and low production, and undoubtedly will be subject to revision as the investigation proceeds in succeeding years.

## MANUFACTURING COSTS

The total cost of processing syrup, through manufacturing plants, has ranged during the past three years from 40 to 50 cents per gallon, including local freight and buying costs. The following figures are the partial costs of one plant per gallon of syrup sold (sales of maple sugar are represented as syrup) during the season of 1919.

| | |
|---|---|
| Plant, office and sales expense | 25.40 cts. |
| Interest on investment | 1.76 cts. |
| Depreciation | 2.46 cts. |
| Local freight | 7.09 cts. |
| Total | 36.61 cts. |

The labor cost included in the first item was 4.01 cents per gallon. To the above costs should be added loss from shrinkage and deterioration of syrup, usually estimated at 5 percent, and insurance charges on the stock in the warehouse. These items with a buying charge of 5 cents make the total cost very close to 48 cents per gallon.

Figures obtained from other dealers give the following approximate processing costs per gallon of syrup:

| | |
|---|---|
| Plant costs (including packages) | 35 cts. |
| Buying costs | 5 cts. |
| Drums (depreciation and maintenance) | 5 cts. |
| Local freight | 5 cts. |
| Total | 50 cts. |

The above figures were obtained during the peak of high prices. They should be lessened in 1922 from 10 to 15 cents per gallon.

## STORAGE

A small quantity of syrup and sugar is held on the farm through the summer and into the following winter, but by far the greater part of it passes into the hands of the dealers within a month or six weeks after the close of the season. An exception to this was found during 1921, when on account of low prices and the large carry-over from the previous year, a larger percentage than usual remained in the hands of the producers. As a rule, however, the bulk of the crop is carried by the manufacturers. About one-third is marketed by them in the two months following sap flow. After this there is very little activity in the syrup market until September 1st, and the bulk of the remaining two-thirds of the crop is put in the hands of the jobbers and retailers during September, October and November. This is also true in the sale of pure and blended syrups. A somewhat different situation exists with regard to commercial sugar, either in tub or block form, and as a general rule it is moved out of the state, or into the hands of the ultimate purchaser, earlier than is the case with syrup.

Syrup is stored by the manufacturers, both in tanks and in the drums in which it is received from the producers. However, as speedily as possible it is put into cans or bottles, either as pure or blended goods, or it is worked up in the form of block sugar. It is best to store syrup at a uniform temperature of 40° to 45° F. Temperatures near freezing, it is said, have a tendency to cause crystallization. Cold storage is not necessary, and a cool, dry cellar, the temperature of which can be held around 60° F. is deemed satisfactory.

The accompanying table gives as a percentage of the value of all shipments for the year, those made by one Vermont manufacturer of pure and blended syrups each month during 1919, 1920, and 1921. The years 1919 and 1920 are not representative, as the shortage of granulated sugar created an unusual demand for maple products and a large portion of the crop was marketed during the summer. It will be noted that in 1921, the heaviest movement was in the autumn.

PERCENTAGE OF TOTAL OUTPUT MARKETED EACH MONTH BY ONE VERMONT DEALER

| | 1919 | 1920 | 1921 |
|---|---|---|---|
| December[1] | 4.3 | 2.4 | 4.4 |
| January | 9.4 | 2.7 | 1.3 |
| February | 2.9 | 5.0 | 1.0 |
| March | 2.9 | 3.9 | 4.6 |
| April | 3.9 | 3.1 | 7.8 |
| May | 14.4 | 11.3 | 4.0 |
| June | 9.9 | 22.5 | 1.5 |
| July | 14.8 | 21.8 | 4.7 |
| August | 9.8 | 10.1 | 13.7 |
| September | 12.3 | 7.8 | 23.0 |
| October | 9.7 | 5.5 | 17.2 |
| November | 5.7 | 3.9 | 16.9 |
| | 100.0 | 100.0 | 100.0 |

## PRESENT MARKETING METHODS

In discussing the marketing of Vermont maple products, the widely varying grades and kinds of goods must be borne in mind.

There are, in the first place, products of first class quality which are sold in the form of either sugar or syrup. This class of products comprises less than one-third of the total production. It is sold, first, by the producers directly to the consumers in quart, half gallon and gallon cans; it is consigned by the producer to commission dealers in eastern markets; a portion is sold locally; and the remainder is sold to the large dealers by whom it is bottled or canned, for the most part, as pure syrup. These are, in addition, the commercial grades of syrup and sugar (No. 2 and No. 3 grades) which make up at least two-thirds of the total production. These grades are sold to manufacturers within the state or to syrup firms in nearby markets. The syrup is sold in bulk in the manufacturer's container, and the sugar, for the most part, in 35-pound tubs. Much of the syrup which falls in the lower grades is converted into block sugar and sold for flavoring pur-

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[1] December, 1918, 1919 and 1920, respectively.

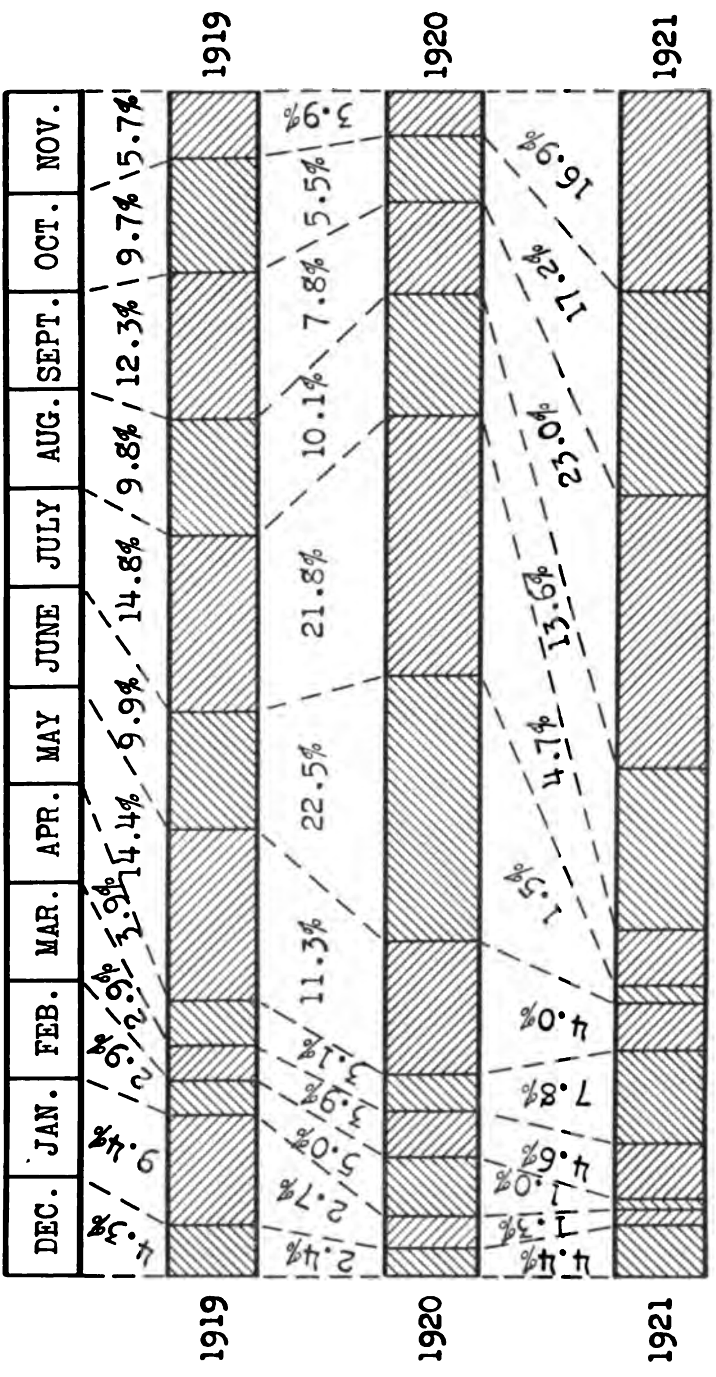

FIGURE 3. Diagram showing the value of monthly shipment of maple syrup and sugar by one Vermont manufacturer, expressed as a percentage of the value of his total shipments for twelve months. December, 1918 to November, 1921.

poses. The manufacturers resell goods of this class to tobacco manufacturers, manufacturers of blended syrups both in and out of the state, manufacturers of confectionery and ice cream makers. It is difficult to obtain definite figures regarding the amount of sugar and syrup which falls within each of the classes mentioned. It is estimated that approximately a sixth of the crop is sold directly by the producers to distant consumers, a tenth used at home and sold locally, a twentieth shipped to commission merchants and two-thirds sold to manufacturers. With this estimate many Vermonters will heartily concur.

The syrup sold in bulk is generally purchased and graded by the local buyer, usually a merchant with whom the farmers trade, and to whom many of them are indebted. The drums are distributed to the producers in advance of the season and when filled, or at the end of the season, are hauled by the farmers to the loading station. On a certain day the syrup is graded either by the local buyer or a man sent for the purpose from the central plant, and the farmers paid in accordance with the flavor, color and density of their product. The entire shipment is then forwarded to the manufacturing plant.

It should be mentioned at this point that a faulty feature of the present marketing system is the failure to make sufficient discrimination between the first, second and third grades of syrup. Before the war, a premium of not more than 25 cents a gallon was paid for No. 1 syrup. During the sugar shortage of 1918, 1919, and the first part of 1920, the demand for maple products greatly exceeded the supply, and a flat price was paid for all grades. In 1921, 15 cents per gallon more was paid for first than for second grade syrup. However, this margin is totally inadequate to encourage the production of fine quality goods. The situation outlined above has retarded improvement in the quality.

## GRADES

The grading of maple syrup now very generally follows the color standards promulgated several years ago by the Bureau of Chemistry of the United States Department of Agriculture. The color scale comprises 20 graduations of color, and the standard solutions are made up of graduated quantities of pure glycerin and a caramel solution.[1] No. 1, the lightest in the scale, is made up of glycerin only, while No. 20, the darkest, contains only the caramel solution. The standard colors are put up in vials of clear glass having the same internal diameters. When syrup in a vial of the same diameter and of glass of

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[1] U. S. Dept. Agr., Bu. Chem., Bul. 174 (1911).

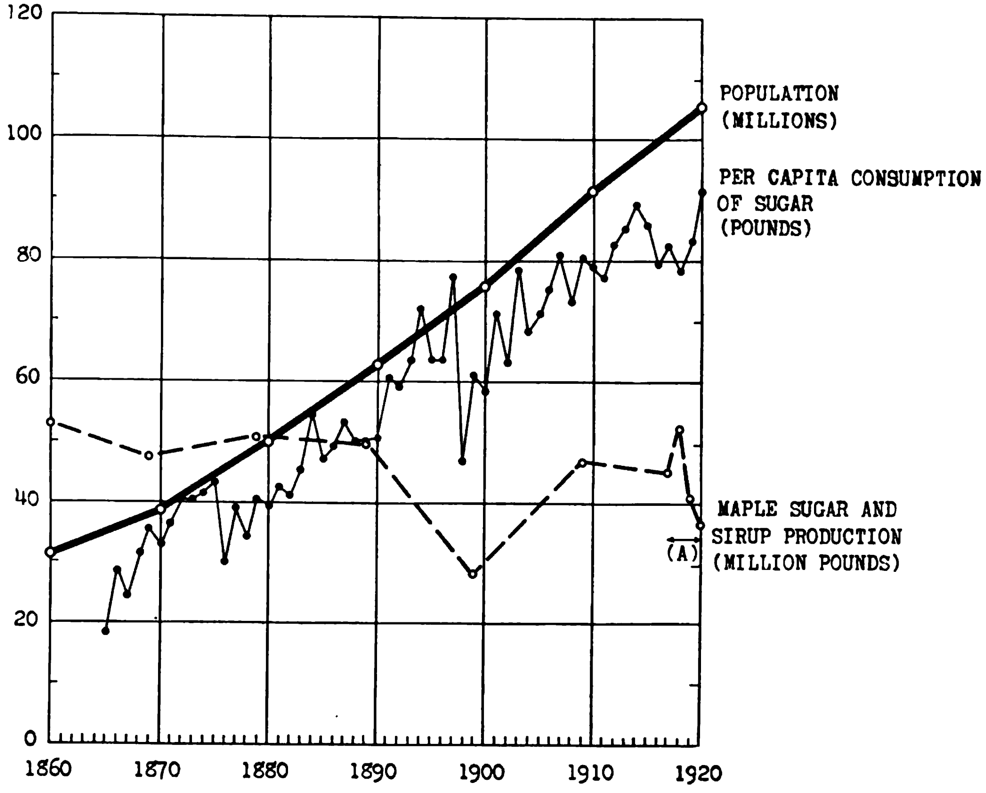

FIGURE 4. Diagram showing population of the United States; per capita consumption of sugar, in pounds, and maple syrup and sugar production, expressed in million pounds, from 1860 to 1920.

A. Figures for maple syrup and sugar production for 1917 to 1920 are from reports of the Bureau of Markets and Crop Estimates. All other figures are from the United States census reports.

similar clearness and color is compared with the color scale, its place in the scale may be quickly determined even by the inexperienced observer. In addition to color, the syrup is tested for density and flavor, although flavor is usually coordinated with color. Density does not directly affect the grade, but a syrup not sufficiently concentrated will soon ferment. The process of condensation to a condition of standard density involves loss through evaporation. Therefore, under-weight syrup is purchased at a price less than that paid for the same grade which is of standard density.

A great deal of the blended syrup, and particularly all of the block sugar is shipped in car lots. However, practically all of the pure syrup and the fancy grades of sugar are shipped in less than car lots. A considerable quantity moves by express and parcel post.

Table 5 shows the farm prices for maple sugar during the years 1917-1921, and table 6 gives the same information for maple syrup. The prices for the most part represent the better grades of maple products, and do not apply to sugar or syrup sold in bulk.

## THE NEED OF ORGANIZATION

Table 7 shows the per capita consumption of sugar in the United States from 1865 to 1920, as given by the "Statistical Abstract of the United States" for 1920. It will be noted that the amount consumed per capita increased from 18.17 pounds in 1865, and 28.45 pounds in 1866, to 91.46 pounds in 1920.

In 1860 the population of the United States was a little over 31,000,000, while in 1920 it had increased to over 105,000,000. In 1860 there were approximately 52,000,000 pounds of maple sugar and syrup expressed in terms of sugar produced in this country, and it can be assumed that the greater part of it entered domestic consumption. In 1920 the production of maple syrup and sugar was less than half this amount, and less than 50 percent of the 1920 production, according to the best figures available, or less than 13,000,000 pounds reached the consumers in the pure form. In spite of the fact that the population of the United States has increased three and one-half times since 1860, and the per capita consumption of sugar is between three and four times as great as in 1865-66, the consumption of maple sugar and syrup as such has actually declined.

The demand created by increased population and consumption has been filled by an increased supply of cane sugar. The demand for table syrups has been met by a greatly increased output of blended syrups.

Blended syrup has come into direct competition with pure maple syrup, and now largely dominates the table syrup market. Lack of organization among the maple-sap producers has made possible the virtual elimination of their product from trade channels. At least 65 percent of the syrup now produced is sold in bulk to manufacturers of blended syrup, or to tobacco manufacturers for flavoring purposes.

From the point of view of the manufacturer, the blended syrup business is more desirable than the pure syrup business. In the first place, it does not require so great an outlay of capital. The maple sugar or syrup required for flavoring purposes represents, as a rule, only 15 to 25 percent of the total product. This must be purchased during or shortly after the maple-sap season, and capital invested in these goods is tied up for a year, or in any event can not be turned over more than once a year. However, cane sugar, which represents 75 to 85 percent of the finished product, can be purchased on the open market at any time, under normal conditions, and in any quantity required. The capital invested in cane sugar, therefore, may be turned over four or five times during the year. In addition it enables the manufacturer to establish a grade which is uniform for each shipment and from season to season. There are seasonal variations in the color and quality of pure maple syrup, and also variations in the product of different producers which make absolute uniformity of grade an impossibility. Furthermore, he has a product comparable with pure maple syrup in appearance which he can offer at a lower price.

The wholesalers, retailers, and the majority of the consumers, are kindly disposed towards blended syrups on account of the uniformity mentioned, the fact that there is a dependable source of supply, and because the article is offered them at a lower price.

Added to this, the manufacturers of blended syrup have been active in extending the sale of their goods. The only competition they have had has been that of unorganized producers unschooled in business practices. It is not surprising, therefore, that the sale of blended syrups has greatly increased in the last ten years, or that the sale of pure syrup has greatly declined. As an example of the extent to which blended syrups have supplanted pure maple syrup, a Vermont manufacturer stated that in 1920 one of his customers bought 600 gallons of pure maple syrup from him and approximately 22,000 gallons of blended syrup. Ten years ago, this customer handled only pure maple syrup and the manufacturer stated that he would have been insulted if he had been offered blended syrup.

Vermont maple syrup, therefore, and this is largely true of all maple sap producing states, has been marketed under a system which has discouraged the sale of the pure product. Instead of being marketed in pint and quart cans or bottles, as one would naturally expect, the greater proportion of the product is sold in 55-gallon drums or as sugar in tubs or 65-pound blocks. Instead of being placed upon the market in the pure form, as a delicacy, it is sold to a large extent in bulk for flavoring purposes. As a bulk article, and as what must be considered a raw product, it naturally does not command a high price. With the exception of 1917, 1918, 1919, and the first part of 1920, when cane sugar was high and scare, the prices paid for maple sugar and syrup to the producers have been little if any above the cost of production. In fact, it would seem that prices paid have usually allowed the farmer a moderate wage for his labor and nothing more.

The most serious shortcoming of the present marketing system, however, is the fact that it has failed to encourage, and as a matter of fact, has actually discouraged the production of maple-sap products of high quality. It is not to be expected that a man will take any great amount of pride in the production of a product which he sells in bulk. During the period of the war, maple syrup and sugar of all grades was sold at a uniform price. In 1921, No. 1 syrup, including fancy quality, was sold very generally for only 15 cents per gallon more than was paid for the No. 2 and No. 3 grades. It is hardly possible that the percentage of No. 1 syrup produced in Vermont has declined. On account of the general introduction of patented evaporators, metal bucket, bucket covers, and other improvements, it has probably increased. However, the fact remains that from 60 to 75 percent of the syrup produced in Vermont is not of desirable table quality, and it would seem that the method of marketing the product must bear the primary responsibility for this condition.

## FORMER VENTURES IN ORGANIZATION

The Vermont Sugar Makers' Association was organized in 1893. It was never the intention of this organization to engage in marketing, but from its inception, marketing problems and cooperative marketing formed active topics of discussion.

A little later the association adopted a label which was supplied to its members at cost, and which they were permitted to use on first grade syrup sold by them to private trade. This label is still used by members of the association and no doubt it has served to a small extent to advertise Vermont goods. However, the fact that the syrup shipped under this brand has not been uniform has nullified largely the advertising value of the label.

In 1901, an effort was made to extend the organized marketing of maple-sap products. Accordingly the "Vermont Maple Sugar Makers' Market" was formed, and a small processing plant was established at Randolph, Vt. This is a stock company and the stock at the time of organization was rather widely distributed among producers. It was assumed that syrup would be processed and sold through the Randolph plant for members and non-members at a fixed charge. However, no contracts were entered into with producers, and it was found that the quantity supplied by them from season to season was uncertain. As the organization's market developed, it was found necessary to buy syrup from the farmers to care for its customers' requirements. This phase of the business developed, while the consignment business declined. At the same time the stock of the "Maple Sugar Makers' Market" apparently came to be held largely by a few individuals. At the present time it operates strictly as a commercial concern. It handles pure goods only, and the management takes a very sympathetic attitude towards the producers' problems. The "Maple Sugar Makers' Market" handles 20,000 to 30,000 gallons of syrup annually and is operating successfully.

In 1920 an attempt was made by a County Farmers' Exchange to market maple-sap products cooperatively with extremely disastrous results. The exchange advanced up to $2.20 per gallon to the producers and accumulated approximately 6,000 gallons of syrup. Very little of this had been sold when the 1920 collapse of the cane-sugar market occurred. In consequence the greater part of the syrup was sold at a heavy loss, most of it through jobbers and commission men. There was also a heavy loss due to leaky cans, evaporation and spoilage, amounting in all to 30 percent. Marketing expenses were also heavy, and it was necessary to reheat practically all syrup received.

During the season of 1921 a national bank in Vermont received and marketed successfully a little over 22,000 gallons of maple syrup. The farmers who delivered syrup to the bank were advanced 75 cents per gallon for No. 1 grade. The bank accepted the farmers' notes for this amount, holding the syrup as security. The syrup was sold direct to the consumers, and a considerable portion of the expense was borne by the bank. It was estimated at the latest report that a dividend of 20 cents per gallon would be paid to the producers of No. 1 syrup.

## THE PRESENT STATUS OF COOPERATIVE MARKETING

The present demand for cooperative marketing is an outgrowth of the low prices received for syrup and sugar during the season of 1921. Even in advance of the maple sap season of 1921, the situation appeared serious. In spite of the fact that $2 per gallon was generally paid for syrup in bulk during 1920, many farmers expected higher prices and refused to sell. During the summer of 1920, coincident with the decline in the price of cane sugar, the demand for maple-sap products practically disappeared and prices fell rapidly. The producers and dealers alike lost heavily and the 1921 season was approached with a large quantity of 1920 syrup and sugar which had been purchased at high prices in the hands of dealers, wholesalers and retailers. There was a great deal of uncertainty, therefore, regarding the marketing of the 1921 crop.

At its meeting in January, 1921, the Vermont Maple Sugar Makers' Association appointed a committee to investigate the marketing of maple-sap products cooperatively. This committee later requested the assistance of the Federal Bureau of Markets in developing a marketing plan. Plans for the organization of a cooperative association and the marketing of maple-sap products were discussed with this committee, and a plan of organization was approved by the association at its meeting in January, 1922. A committee was appointed to proceed with the formation of local associations, which, later, were federated in a central exchange.

## COOPERATIVE MARKETING DIFFICULTIES

Enough has been said regarding the nature of the industry to indicate that the processing and marketing of maple-sap products is a complicated problem. A processing plant and expensive machinery are required and the operation of the plant requires a fair amount of technical skill. The marketing of maple syrup is at least as difficult as that of other farm products. There is apparently a lack of enthusiasm among wholesalers and retailers regarding pure maple syrup, and a consumers' demand must be built up. On the other hand, the product lends itself to preparation in such a variety of ways that an attractive brand and standard product should be quite easily established.

The greatest drawback to the development of cooperative marketing, however, is the general attitude of the producers. The Vermont farmer is naturally an individualist, and is slow to undertake new ventures. Cooperative marketing is not extensively developed and the producers do not possess the cooperative point of view. They instinctively approach the problem as simply an extension of the private trade in which so many of them are engaged.

These handicaps are undoubtedly common to all unorganized producers and can be overcome only through experience in organization. They are not considered sufficiently great to preclude organization, but they do indicate that extreme caution must be exercised.

There must be taken into consideration also the fact that a great many maple-sap products are indebted to local merchants, who act as buyers for the large dealers. These men are under obligation to sell their syrup to these merchants and are not free at the present time to join a cooperative association.

Financial difficulties are also considerable. The most serious is the difficulty of carrying the maple-sap products through the summer. The producers in nearly all cases depend upon money received for their maple-sap products to give them the ready cash necessary to start their farming operations and pay taxes and bills contracted at the local stores through the winter. To merchandize maple-sap products scientifically they must be distributed to the trade throughout the year. In the case of syrup there is an active demand for about two months after the sap season. Demand then falls off until about the first of September and there is then an active demand through the fall and winter months. Hence it is necessary to carry two-thirds to three-fourths of the product for approximately six months, and it seems equally necessary to advance the producers at least a portion of the value of these products.

## THE PROBLEMS

The problems which now confront the Vermont producers of maple syrup and sugar are briefly the following:

1. To improve the methods of gathering and concentrating the sap in order to increase the output of first grade sugar and syrup.
2. To standardize grades, packages and handling methods.
3. To provide marketing machinery for the regular and uniform distribution of pure maple-sap products to the consumers.
4. To widen the market and increase demand for pure products.

On the average, less than one-third of the maple syrup and sugar produced is of sufficiently high quality to sell readily in the pure form. The remainder must be sold as a bulk product and is used largely for flavoring. No. 1 goods, if properly marketed, will bring the producers profitable returns and will advertise the state and the maple-products industry. On the other hand, low grade syrup, in the future, will bring very little if any margin over the cost of production. It does not reach the consumer in the form of a pure product and in no wise adds to the prestige of the maple-sap industry. As a matter of fact it makes possible a large part of the blended syrup business which is strictly competitive with pure syrup.

Methods of producing syrup of a desirable quality have been established for many years. If a farmer now produces a syrup or sugar of low quality, it is either because it has not been worth his while to inform himself as to improved methods or because it has not been worth his while to put into practice the information which he possesses. And the facts of the case are that low grade syrup has brought almost as much as the finest quality. No improvement in production methods can be expected until a marketing system is adopted which will reimburse the producer of No. 1 syrup in accordance with quality.

The standardization of grades and packages implies concerted action on the part of the producers, or on the part of the dealers and producers. With regard to grades there is very little to be done. The color standards which have been promulgated, together with proper allowances for flavor and density, constitute a thoroughly satisfactory grade standard. The standard must be given publicity, and the support of dealers and producers secured. Following this comes the practical problem of supplying to consumers a grade of pure syrup—uniform year after year in color and flavor—packed in standard containers. In order to secure and maintain uniformity of grade the syrup must be processed and canned at a central point.

The regular and uniform distribution of pure syrup and sugar to the consumers can not be accomplished under the present marketing system. The farmer working as an individual can not bring this about, because his marketing is necessarily spasmodic and his product is lacking in uniformity. The greater part of the syrup sold by the producer direct to the consumer is shipped within two months after the sugar season. No provision is made for the demand which arises the following fall and winter. Efficient merchandizing of the pure product demands a uniform distribution while the demand is active.

To the average manufacturer, the pure syrup business is largely a side line. His efforts are naturally most strongly directed to the disposal of his main product, which may be commercial maple sugar or blended syrup. It seems evident that only through organization can the producers hope to control the distribution of their crop, or make available a regular, uniform supply preventing gluts and shortages.

The problem of increasing the demand for pure maple syrup and sugar actually exists and must be met. It is a problem which the producers must solve themselves. No one else is interested in extending the market for Vermont maple syrup. The dealers naturally are interested in making a profit. It is immaterial to them whether they handle Vermont maple syrup or a blended product. The consumer will accept what he can buy and no doubt consider it entirely satisfactory. Now to increase the demand for any product the producers must do three things: They must organize, they must standardize, and they must merchandize their products. There does not seem to be any way in which they can avoid these activities.

It will be noted that in this discussion, reference is made only to pure sugar and syrup which is relatively high in quality. So long as low grade syrup and sugar are produced, the manufacturers of blended syrup, the tobacco manufacturers, or dealers supplying this trade offer the best market. The efforts of a producers' organization, however, should be directed towards increasing the production of and extending the market for high quality products. It is this class of goods which will bring them profitable returns and enhance reputation.

The successful solution of the problems already discussed presupposes organization as the necessary first step. The plan of organization which follows, has been recommended to the Vermont producers and is one which it is believed will best meet their needs. However, no form of organization will of itself insure success. No organization can operate successfully without efficient direction and the loyal support of the members. And if the organization is to be truly cooperative and successful, all of its members, in so far as their abilities and opportunities permit, must assist in the solution of the problems.

## FORM OF ORGANIZATION

The basis of the plan suggested is the local association, made up of producers using the same shipping point, or residing in the same town, or in any geographical division which will make a compact unit. The purpose of the local association is to act as a unit for the dissemination of market information among its members, information relative to methods of gathering and concentrating sap, and other matters of general interest. It will also act as an assembling and shipping unit, and the secretary or manager of the local association will store or ship the syrup as directed by the central manager.

The local associations are incorporated with the provision that the authorized capital stock be not more than $2,500. The par value of the shares has been placed at $10, and each member of the association must be a stockholder to the extent of at least one share. No member can hold more than 10 percent of the stock of the association and dividends are restricted to 6 percent.

In the crop contract between the local association and its members, each member agrees to loan to the association upon demand an amount equivalent to five cents for each spout driven the previous season upon the farm which he now occupies. In return for the loan, the association will issue certificates of indebtedness payable in five annual installments. This loan fund will be used by the local association to purchase the common stock of the central exchange.

The members of the local association, each of them being entitled to one vote irrespective of the amount of stock which he owns, elect their directors, who in turn will elect the officers of the association. The members of the local association will also elect a director to represent them upon the board of the central exchange.

The Vermont Maple Producers' Cooperative Exchange, Inc. (the central organization) is incorporated under that section of the Vermont law which makes provision for the incorporation of cooperative associations. The common stock of the exchange is owned by the local associations. The associations control absolutely the policy of the exchange and are thereby assured that it is operated for their benefit and the benefit of their members. Each director holds the proxy of the association which he represents and is entitled to one vote in all meetings of the exchange. The directors elect from among their own members an executive committee, which is charged with the supervision of the business of the exchange. The executive committee selects a manager, who has direct charge of processing and marketing.

## MARKETING METHODS

The organized producers can not be guided entirely by present methods of marketing maple-sap products. New methods must be developed, particularly for the sale of No. 1 products. These can not be outlined in any detail at the present time as it is impossible to foresee all the conditions which may arise. In addition, it would be a mistake to attempt to make the practices and policies of the exchange conform to a rigid plan. The suggestions offered are in the nature of methods for immediate relief, taking into consideration the fact that the industry is not strongly organized, is not in a strong financial position and is lacking in marketing experience.

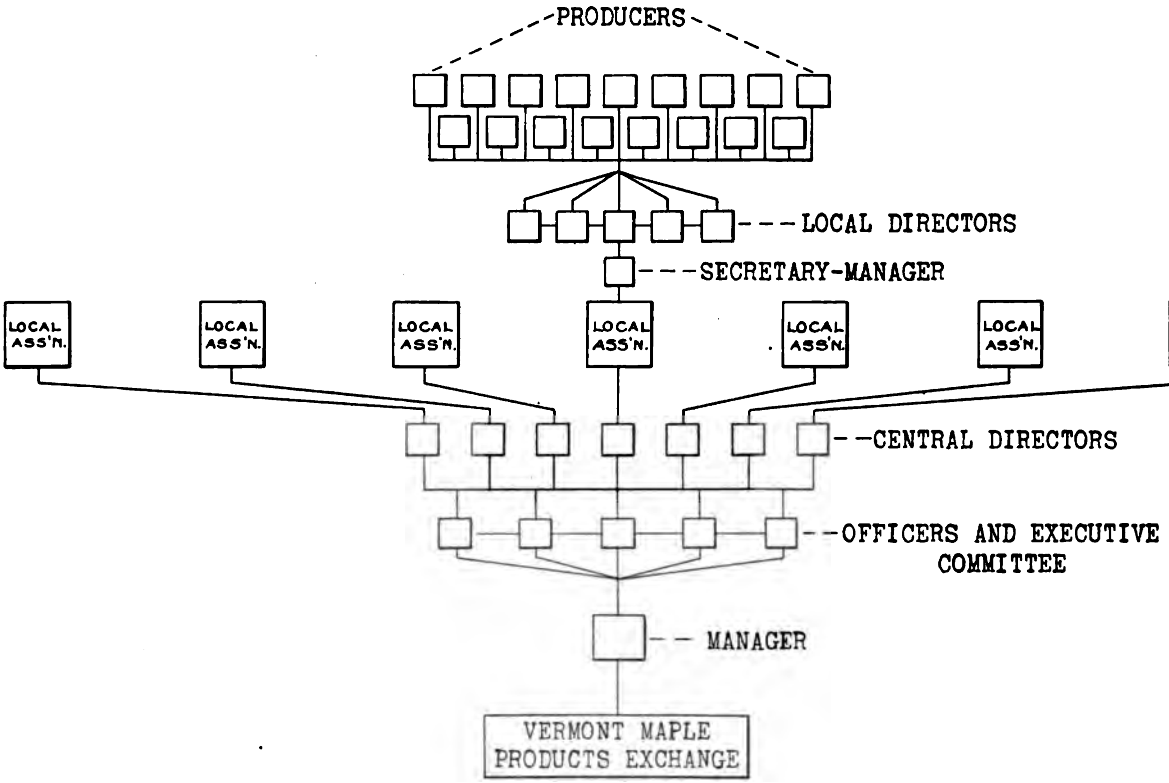

FIGURE 5. Diagram showing the relation of the producers and the local associations to the Vermont Maple Products Cooperative Exchange.

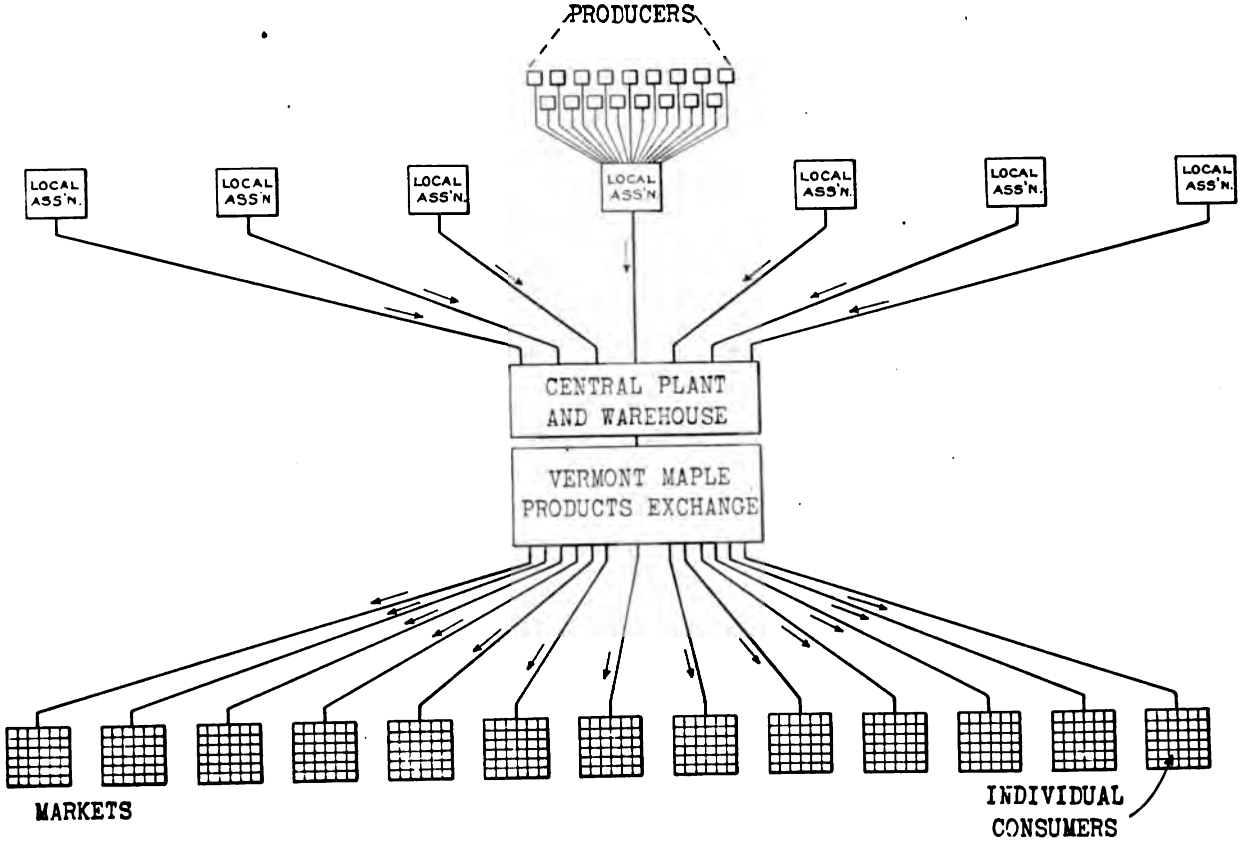

FIGURE 6. Diagram showing the marketing of maple-sap products through the Vermont Maple Products Cooperative Exchange.

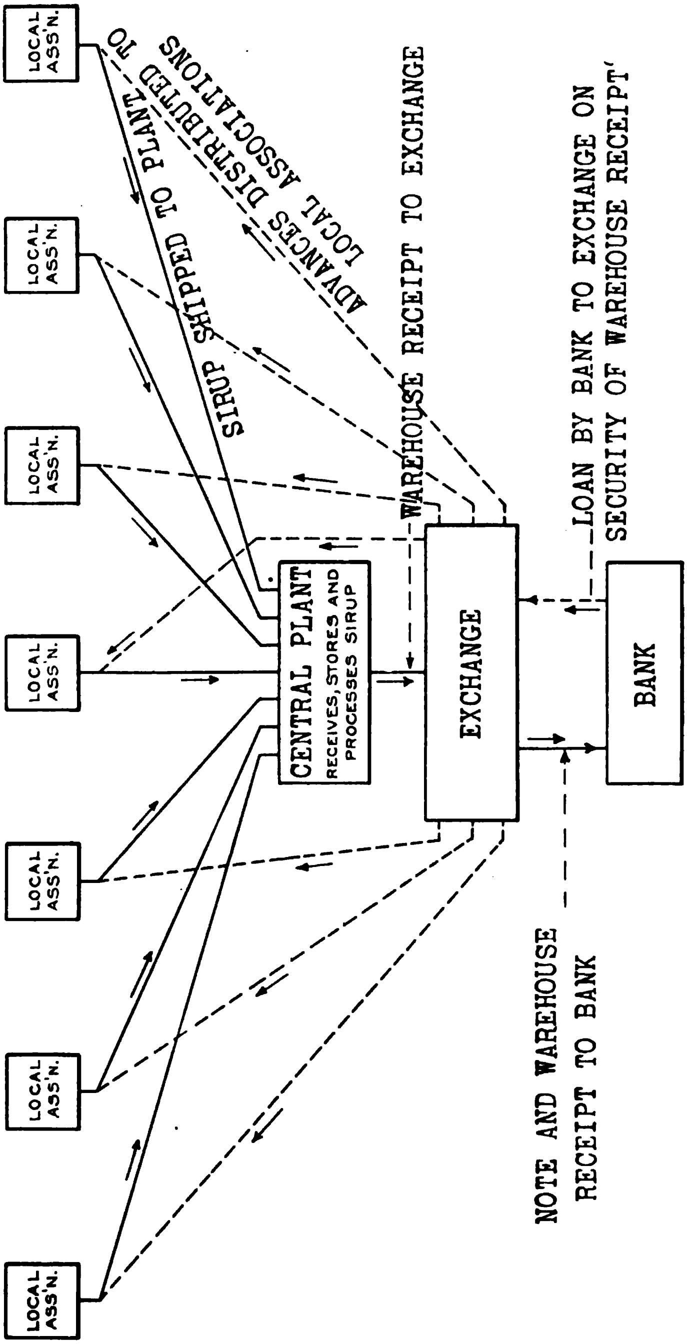
LOCAL ASS'N.
LOCAL ASS'N.
LOCAL ASS'N.
LOCAL ASS'N.
LOCAL ASS'N.
LOCAL ASS'N.
LOCAL ASS'N.
SIRUP SHIPPED TO PLANT
ADVANCES DISTRIBUTED TO LOCAL ASSOCIATIONS
WAREHOUSE RECEIPT TO EXCHANGE
LOAN BY BANK TO EXCHANGE ON SECURITY OF WAREHOUSE RECEIPT
CENTRAL PLANT
RECEIVES, STORES AND PROCESSES SIRUP
EXCHANGE
BANK
NOTE AND WAREHOUSE RECEIPT TO BANK

FIGURE 7. Diagram illustrating a method of financing advances to producers through loans secured by warehouse receipts.

As has already been mentioned, syrup and sugar of poor quality, which might be termed "bulk goods," should be sold direct to Vermont dealers. This class of goods should be disposed of as early as possible while the blenders and tobacco manufacturers are in the market. Possibly the producers will later develop a more profitable market for this low grade product. It is not inconceivable that they may even enter the blended syrup business. Under present conditions, however, it is a sound business policy to dispose of it quickly for cash.

In regard to their No. 1 product the largest quantity can be disposed of in the form of table syrup. For the present the greater part of this product must be sold through the usual trade channels, that is, to wholesale grocers and retailers. At the same time a hotel and restaurant trade can undoubtedly be established. The producers, however, must go on the market in direct competition with other dealers in pure syrup. They will make their sales because the quality of their product is superior to that of other brands, or because they offer more favorable prices. The wholesalers and retailers offer the obvious market for the greater part of the product and though other outlets may be developed later, they must be depended upon to absorb a large portion of the product at the present time.

At the same time, a retail department should be organized and a consumer clientèle established. This class of business is somewhat more costly to handle than are sales to retailers. However, the returns to the producers will be larger and, once created, a market of this kind will be largely unaffected by conditions which cause depressions in the ordinary trade channels. About 17 percent of the crop is now being sold by the producer directly to the consumer without organization, and with practically no advertising. In addition, the product is compact and, for that reason, can be shipped economically by parcel post or express for considerable distances.

## PREVAILING RETAIL PRACTICES

A survey to determine the prevailing practices in marketing maple-sap products was made in Philadelphia, New York and Boston during the spring of 1922. At this time syrup manufacturers, brokers, commission merchants, wholesale grocers and retailers were visited. No attempt will be made to discuss separately conditions found in each city. In general, a much more active demand was found in Boston than in Philadelphia, with New York about midway between the two.

The survey determined first of all that the demand for pure maple

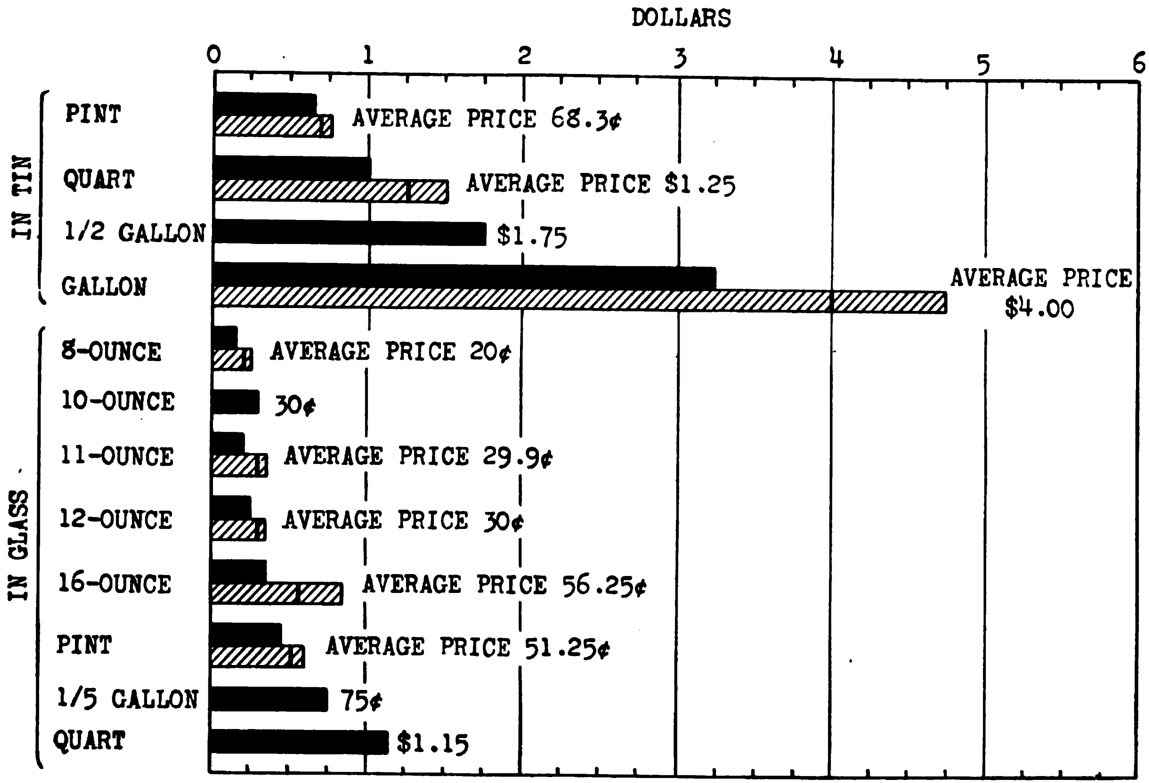

FIGURE 8. Diagram showing the range of retail prices in 20 moderate prices stores of maple syrup in various containers, New York City, March, 1922. The solid black blocks indicate the lowest and the shaded blocks the highest prices. Black vertical lines in the shaded blocks show the average price. Where only one price was quoted it is represented by a solid black block.

syrup is confined largely (*a*) to comparatively wealthy customers served by fancy grocers, and (*b*) to individuals reared in maple-sap districts, or accustomed to maple products since childhood. This latter class, in many instances, orders directly from the producers. The wealthy purchasers of maple products buy from their grocers.

At the same time pure maple syrup is sold in many, but not all, chain stores and grocery stores serving people in moderate circumstances. However, the amount sold in stores of this kind is very much less than the quantity of cane and blended syrup sold during the same period. The syrup man for a system of 1,200 chain groceries with headquarters in Philadelphia stated that their sales of pure maple syrup were 1/400 of their cane and blended syrup sales. Another chain of 5,200 retail stores, located north of the Potomac and Ohio Rivers, reports that their sales for last year were approximately 25,000 cases (2 dozen 11-ounce bottles) of pure maple syrup, 25,000 cases of maple blend and 200,000 cases of other syrups.

These stores and others of the same class attribute the greater sales of cane syrups entirely to the lower price. A comparison of the prices asked for maple syrup and for other syrup is shown in table 8. The 25 stores represented in this table were chain stores, or small groceries catering to people in moderately comfortable circumstances. All sold syrup of some kind, but pure maple goods were found in only four.

The high class hotels and restaurants are also customers for pure maple syrup. However, they do not use the quantity of syrup that is commonly supposed. Each of the large, first-class hotels in New York City consumes, on the average, about 300 gallons of maple syrup annually. These hotels must have a light colored syrup, made from the "first-run" sap and put up in gallon cans.

The fancy groceries catering to the best trade for the most part prefer maple syrup in cans and in quart, half-gallon and gallon packages. The small stores prefer syrup in bottles, and in smaller units. An 11-ounce bottle appears to be the most popular size. These trade preferences are well established. Particularly is it necessary to furnish the small groceries with syrup in a small container, as the majority of their customers purchase supples from day to day and do not care to have a large quantity on hand. Figure 8 represents graphically the highest, lowest, and average price charged for maple syrup in various sizes and styles of containers in 20 retail groceries located on Fifth Avenue, Madison Avenue, Park Avenue, and Lexington Avenue, between 54th and 104th Streets, New York City. Out of 40 stores visited, only the 20 represented in figure 8 handle pure maple syrup.

The intensity of the demand for pure maple products is determined also by the price of cane sugar. If the price of cane sugar is high, the price of cane-sugar syrup is high, and the use of pure maple products will be encouraged. This situation existed during the war and the two years immediately following. At this time prices paid for maple sugar and syrup reached unprecedented heights. At the present time, the price of cane sugar is lower than it has been in years, and cane-sugar syrup can be manufactured at a low cost.

It is evident that at present only a comparatively small percentage of the people in the United States will buy maple products at a price greatly in excess of that at which cane and corn products may be obtained. At the same time it has been shown that maple syrup can not be profitably produced at a competitive price level.

The desire for pure maple-sap products, therefore, must be stimulated by carefully directed publicity. So long as the producers were not organized it was impossible to take this step. Following organization it is necessary to secure a standard article and to bring this about necessitates only adherence to grade standards already established. With the establishment of grades, maintained and guaranteed by organized producers, it is possible to benefit by an advertising campaign.

The production of maple sugar and syrup has a strong hold on the imagination of many people. Stories concerning syrup making are always interesting reading, particularly if these are illustrated with forest scenes showing the maple sap being collected and evaporated. No doubt many such illustrations would be used in Sunday newspapers.

An educational motion picture which tells the story of maple syrup and sugar manufacture would be very helpful. If made available without charge, it would be shown in many moving picture theatres in the course of a year. Such a motion picture could not fail to persuade many who know little about pure maple-sap products to become tentative and perhaps permanent customers.

All this publicity can be obtained at comparatively little cost by reason of the "news interest" of the product. The producers of course must take advantage of this publicity by advertising their own trade-mark to the public. Whether such advertising is national or local would of course depend upon the quantity of the products to be handled, and the results determined by a survey of the situation made by a trained advertising specialist.

## SUMMARY

1. In spite of the high reputation of Vermont maple sugar and syrup, the demand for these products has not kept pace with population, or with the increased consumption of sweets by the American people. Pure maple syrup has been supplanted by cane-sugar or corn syrups and by blended syrups. A large proportion of the wholesale and retail trade, and most consumers, are ignorant of or indifferent to pure maple goods. This condition is due largely to the fact that the industry has not been organized systematically to market its products.

2. At the present time, at least two-thirds of the Vermont production is sold in bulk, and used for flavoring purposes. As bulk products, Vermont maple syrup and sugar have been sold at low prices, except during periods of cane sugar scarcity, and the tendency has been to pay little attention to quality.

3. These conditions provide a marketing problem of real difficulty. The Vermont producers can not safely assume that the reputation of their maple-sap products makes an organized marketing effort unnecessary. Such an assumption has been partially responsible for their failure successfully to market their products in the past. Although many consumers are aware of, and accept for the most part, the traditional reputation for high quality which Vermont maple-sap products possess, something more than tradition is necessary to convert any number of them into customers.

4. The producers have a vital interest in the conditions under which their maple-sap products are marketed. The existence of their industry and their own welfare demand that all of their products be sold at profitable average prices. No other class—neither the dealers, the wholesale and retail trade, nor the general public—has the same vital interest in marketing conditions as have the producers, and can not be expected to take active steps to improve conditions. Such action must be taken by the producers themselves, and presupposes organization. The formation of the Vermont Maple Products Cooperative Exchange, Inc., is the first step toward better marketing.

5. The second step toward better marketing is the adoption and maintenance of standard grades. Satisfactory grade standards have already been promulgated. These must be maintained and guaranteed by the organized producers in order that their customers may have the fullest confidence in their products and their business methods. At the same time an educational campaign should be carried on to improve farm processing practices and to increase the high quality output.

6. Merchandizing methods, which include advertising, must be developed. Maple-sap products must be prepared in a form and packed in containers which will meet the needs of consumers and attract new customers. It is essential that demand for Vermont maple-sap products be extended and strengthened and a systematic advertising campaign is necessary to accomplish this.

7. The traditional reputation of Vermont maple sugar and syrup, and the nature of the product, makes it possible to develop many successful merchandizing methods. However, only such marketing practices as are comparatively simple and possible of immediate adoption are recommended in this bulletin. As a matter of sound business policy, a newly organized association of necessity concerns itself largely with the problems that are most pressing, and the methods adopted should be those which are most direct and which have passed the experimental stage. It is difficult, at this time, to indicate in any detail the future marketing practices of the maple-sap producers because it is impossible to foresee the trend of their business. As the organized producers gain strength and experience their merchandizing and business practices will undoubtedly develop through a process of evolution along lines that are substantial and sound.

# APPENDIX

## ARTICLES OF ASSOCIATION FOR LOCAL ASSOCIATIONS

ARTICLES OF ASSOCIATION OF THE..............................
..............................COOPERATIVE ASSOCIATION, INC.

**We, the undersigned, do hereby voluntarily associate ourselves together as a cooperative corporation under the laws of the State of Vermont, and have adopted the following articles of association, viz.:**

### ARTICLE I

**The name of this corporation shall be................................. Cooperative Association, Inc.**

### ARTICLE II

**The purposes for which this corporation are formed are:**

**To encourage better and more economical methods of drawing and evaporating maple sap; to provide better facilities and agencies through which the product of its members may be processed, canned, bottled, graded, packed, advertised, marketed and distributed, upon a uniform plan and in such manner as to bring about higher standards of quality and wider and more uniform distribution; to cultivate and develop a cooperative spirit within the producing communities, and to perform any other work or service which may tend to further and safeguard the general interest of the business, the industry, and the members of this Association. This Association is or-**

ganized for the purpose of mutual help in the accomplishment of each of the purposes set forth herein and is not to be conducted or operated for profit.

To act as agent for stockholders in the handling, processing, manufacturing, preparing for market, and sale and disposal of maple sap and all products thereof in every form whatsoever.

To purchase from its stockholders or others maple sap or any of the products thereof, and to handle, process, manufacture and prepare such maple sap and products thereof for market, and to sell and dispose of the same.

To purchase, lease, hire or otherwise acquire any lands, tenements, warehouses, plants, machinery, or other property, and to acquire, erect and construct and reconstruct any buildings, warehouses, plants, machinery, or other things necessary or convenient for the accomplishment of its purpose.

To borrow money, and to pledge, mortgage or hypothecate corporate property, and to execute all papers and do all other things necessary or expedient for the transaction of its business; and to make advances to its stockholders.

To do each and everything necessary, suitable or proper, and by any lawful means and agencies, for the accomplishment of any of the purposes, or the attainment of any one or more of the objects herein enumerated, or which shall at any time appear conducive to or expedient for the business, protection, or benefit of this corporation.

### ARTICLE III

The principal place of business of this corporation shall be located at ............................ in the county of..........................., in this State.

### ARTICLE IV

The capital stock of this corporation shall be TWENTY-FIVE HUNDRED DOLLARS, divided into 250 shares of the par value of Ten Dollars each. No shareholder shall hold shares of a greater par value than $250.

### ARTICLE V

Each common stockholder shall have one vote and only one vote in all matters pertaining to the management of the corporation without regard to the number of certificates or shares of stock held by him, and a statement to this effect shall appear on the face of all certificates of stock.

### ARTICLE VI

The interest or dividends on the paid-up capital stock of the corporation shall not exceed six percent per annum.

### ARTICLE VII

There shall be set aside annually not less than 10 percent of the net profits of the corporation for a reserve fund until there is accumulated a fund of not less than 30 percent of the paid-up capital stock.

### ARTICLE VIII.

The remainder of the earnings or any part thereof shall be distributed by a uniform dividend upon the amount of purchases or sales through the corporation by the shareholders, or the amount of raw material furnished to or business done through the corporation by the shareholders, after deducting all charges and expenses; said net profits or earnings shall be distributed as often as once in twelve months.

### ARTICLE IX

Not more than 10 percent of the capital stock of such corporation shall be owned by any one member.

### ARTICLE X

We hereby waive all requirements of the statutes of Vermont for notice of the first meeting for organization, and appoint........................ ...........................................................as the time and place of holding said first meeting.

Dated at.......................in the county of..................this ..........day of....................A. D. 19.....

The names and residences of the incorporators and the amount of stock subscribed by each are as follows:

| NAME | RESIDENCE | AMOUNT |
|---|---|---|
| ........................ | ........................ | ........................ |
| ........................ | ........................ | ........................ |
| ........................ | ........................ | ........................ |
| ........................ | ........................ | ........................ |
| ........................ | ........................ | ........................ |
| ........................ | ........................ | ........................ |

## LOCAL ASSOCIATION BY-LAWS

BY-LAWS OF THE...........................COOPERATIVE ASSOCIATION, INC.

### ARTICLE I.—*Name, etc.*

SECTION 1. The name, place of business, capital stock and purposes of this corporation are set forth in its articles of association which are referred to and made a part of these by-laws to the same extent and effect as though written herein.

### ARTICLE II.—*Membership*

SECTION 1. Any bona fide producer of maple-sap products, and landlords who directly or indirectly receive rent in maple-sap products in any territory tributary to the shipping points of this Association may become a member of the Association if acceptable to the Board of Directors by agreeing to comply with the requirements of these by-laws and by purchasing one or more shares of stock.

SEC. 2. At any time that the Board of Directors in its discretion determines that a member has ceased to be a bona fide producer of maple-sap products, or in the event that a member shall remove from the territory tributary to the shipping point of this Association, the Association may through its Board of Directors elect to purchase his shares of stock and cancel his membership upon tender to him of the book value of his shares, together with any interest or refund due and unpaid less any indebtedness then due the Association. The substance of this by-law shall appear on all certificates of stock.

### ARTICLE III.—*Fiscal Year, Meetings.*

SECTION 1. The fiscal year of the Association shall commence *January 1st* and end on *December 31st.*

SEC. 2. All meetings of the stockholders shall be held at the office of the Association in the town of......................, Vermont. Directors' meetings shall be held at said office, unless the call therefor specifies some other place of meeting.

SEC. 3. Regular annual meetings of the stockholders or members shall be held on the..........day of......................in each year, at........ o'clock in the................noon.

SEC. 4. Special meetings may be called at any time by the President. He shall call such meetings whenever one-fifth of the members shall so request in writing.

SEC. 5. Notice of the annual meeting shall be mailed by the Secretary to each member at least ten days previous to the date of meeting, and such notice shall be published in a local newspaper not less than five days previous to the date of meeting. At least five days before the date of any special meeting the Secretary shall mail notice of such meeting to each member, which shall state the nature of the business to be transacted at such meeting.

### ARTICLE IV.—*Quorum*

SECTION 1. One-fourth of the members in good standing shall constitute a quorum for the transaction of business at any meeting.

### ARTICLE V.—*Directors and Officers*

SECTION 1. There shall be elected annually from the members of the Association a board of five directors. The members shall also annually elect a clerk, who shall be a member and who shall be, *ex-officio*, clerk of the board of directors. Directors shall hold office for one year and until their successors are elected, qualified and have entered upon the discharge of their duties. Vacancies in the offices of directors, and clerk, shall be filled for the unexpired term by the members at an annual meeting or a special meeting called for that purpose. But the directors may appoint a member to fill such vacancy until such annual or special meeting can be held.

SEC. 2. The Board of Directors shall meet within ten days after the first election and after each annual election, and shall elect by ballot a president, and a vice-president from among themselves, and a treasurer who may or may not be a member of the Association. They shall also choose three auditors from the members who shall not hold any other office in the Association. Such officers and auditors shall hold office for one year or until their successors are duly elected and qualified. Any vacancy in the offices of president, vice-president, treasurer and auditors shall be filled for the unexpired term by the remaining directors. Officers so appointed to fill vacancies shall hold office until the next annual meeting or until their successors are duly elected and qualified.

SEC. 3. Three members of the Board of Directors shall constitute a quorum at any meeting of the board.

SEC. 4. Any director or the Clerk of the Association may, for cause, at any annual or at any special meeting called for the purpose, at which a majority of the members shall be present, be removed from office by vote of not less than two-thirds of the members present. Such director or officer shall be informed in writing of the charges at least five days before such

**meeting and at such meeting shall have an opportunity to be heard in person, by counsel and by witnesses, in regard thereto. The Board of Directors may summarily remove any officers elected or appointed by them.**

**SEC. 5. The members of this Association may at any annual meeting or at any special meeting following a notice served as herein provided elect a director of the Vermont Maple Products Cooperative Exchange who shall represent and act for this Association in all of its affairs pertaining to said Exchange and shall hold office for the period specified in the by-laws of the Exchange.**

### ARTICLE VI.—*Duties of Directors.*

**SECTION 1. The Board of Directors shall manage the business and the affairs of the Association and make the necessary rules and regulations, not inconsistent with law or with these by-laws, for the management of the business and the guidance of the officers, employees and agent of the Association.**

**SEC. 2. The Board of Directors of this Association are hereby authorized to employ such agents, employees and persons as shall be necessary for carrying on the work of the Association, to define and prescribe their duties, to fix their compensation and discharge them.**

**SEC. 3. The Board of Directors shall require the Treasurer and all other officers, agents and employees charged by the Association with responsibility for the custody of any of its funds or property, to give bond with sufficient surety for the faithful performance of their official duties.**

**SEC. 4. The Board of Directors shall meet on the first and third Saturdays of each month during the sap-flowing period and at other periods as often as may be deemed necessary by the Board of Directors. Special meetings of the board shall be held upon call of the President or upon written request of three members of the board.**

### ARTICLE VII.—*Duties of the Officers*

**SECTION 1. The President shall (*a*) preside over all meetings of the Association and of the Board of Directors; (*b*) call special meetings of the Association and of the Board of Directors and perform all acts and duties usually required of an executive and presiding officer; (*c*) shall sign as President, with the Treasurer, all notes, deeds, mortgages, contracts, and other instruments except checks, on behalf of the Association.**

**SEC. 2. In the absence or disability of the President, the Vice-President shall preside and perform the duties of the President.**

**SEC. 3. The Clerk shall keep a complete record of all meetings of the Association and of the Board of Directors. He shall give all notices required by law and these by-laws, in the manner therein or herein indicated. He shall be the custodian of the corporate seal. He shall keep a complete record of all business of the Association and make a full report of all matters and business pertaining to his office to the members at their annual meeting and make all other reports required by law. He shall perform such other duties as may be required of him by the Association or the directors.**

**SEC. 4. The Treasurer shall receive and disburse all funds and be the custodian of all property of the Association. He shall sign as Treasurer all checks, and, with the President, all notes, deeds, mortgages, contracts and other instruments (except checks) on behalf of the Association. He shall make a full report of all matters of business, including the keeping and**

reporting a true and accurate account of funds, pertaining to his office; such reports to be made to the members regularly at their annual meeting, and at other times when called for by the members or directors. He shall perform such other duties as may be required of him by the Association or the directors.

### ARTICLE VIII.—*Finance*

SECTION 1. At the time of uniting with the Association or at any time thereafter, when called upon by the Board of Directors, each member shall loan or execute a negotiable note to the Association for an amount equivalent to five cents per spout for each and every spout driven during the season last past by the member or upon the farm which the member now owns, or occupies. The money obtained in this manner shall go into a special loan fund and receipts therefor shall be issued in the form of certificates of indebtedness. If this loan is made in the form of a negotiable note no certificates of indebtedness shall be issued to the maker of such a note until the same has been paid in full. This loan fund may be used to purchase shares of stock in the Vermont Maple Products Exchange and the balance thereof may be employed as the Board of Directors may direct for furthering the interest of the Association.

SEC. 2. For the purpose of providing finances to cover maintenance, operation and to provide sufficient funds to cover depreciation, retire loans and create a working fund, the Association shall receive the proceeds of all sales made by it for its members and shall deduct a percentage assessment on the products sold through the Association, the amount of such percentage to be fixed by the Board of Directors.

SEC. 3. Certificates of indebtedness, as herein provided, shall draw interest at the rate of five percent per annum.

SEC. 4. At the end of each fiscal year each member shall receive a certificate showing the amount of money which he has paid during the year toward the retirement of the special loan funds and for other purposes as set forth in Sections 1 and 2 of this Article.

### ARTICLE IX.—*Grading and Inspection*

SECTION 1. All products offered by the members for sale through the Association shall be delivered to the Association, as directed by the Manager, in prime condition for grading, processing and shipping.

SEC. 2. All maple-sap products offered for sale and shipment shall be inspected before shipment and if any packages or containers shall be found to be in bad condition they shall be prepared for shipment at the expense of the owner.

### ARTICLE X.—*Contracts*

SECTION 1. Every member of this Association shall enter into a contract with the Association covering the sale of his maple products and in the form required by the Board of Directors.

### ARTICLE XI.—*Duties and Rights of Members*

SECTION 1. A member shall have the right to give away or retain for his own use such of his maple products as he may wish, but he shall not sell any product contracted to the Association to an outside party, except products offered to and rejected by the Association.

SEC. 2. Each member shall have a number or mark which will be attached to every barrel, cask, drum, or other container filled by him or under his direction for shipment and sale through the Association.

SEC. 3. Each member of the Association shall have only one vote. This shall not be exercised except when all debts and dues owed by him to the Association have been fully paid. Voting by proxy shall not be permitted. Except in the case of the removal of a director or officer, as provided in Article V, Section 4 of these by-laws, absent members may vote on specified questions by ballots transmitted to the Secretary of the Association by registered mail, and such ballots shall be counted only in the meeting at the time at which such vote is taken.

SEC. 4. Membership in the Association shall be continuous, but after three years' membership any member may withdraw from the Association on December 1 of any year, by giving written notice of such withdrawal at least ten days before withdrawal. Such withdrawal, however, shall not affect any right or lien which the Association has against the retiring member or his property until his indebtedness to the Association is fully paid, nor release him from the necessity of delivering to the Association any maple products under contract.

SEC. 5. Any member having a grievance or complaint against the Association may appeal to the Board of Directors. No member shall be suspended or expelled or deprived of the benefits of the Association without having charges preferred against him, reasonable notice thereof having been given and a hearing before the Board of Directors at which he may offer witnesses.

### ARTICLE XII.—*Expenses and Payments*

SECTION 1. The expenses of operating the Association shall be met by a percentage charge laid upon returns for products sold or by a uniform fixed price per pound or per gallon and the amount of such charges, and fixed price per pound or gallon shall be fixed by the Board of Directors.

SEC. 2. All maple products of the same nature and grade shall be settled for upon the average price basis during such periods as the Board of Directors may determine. Partial payments for such products shall be made from time to time as the market sales and collections justify and full payment shall be made at the end of such period.

### ARTICLE XIII.—*Miscellaneous*

SECTION 1. The seal of the Association shall be circular in form with an outer border and the name of the Association around its periphery and the figures "1922" in the center.

SEC. 2. Any member who fails to live up to his agreement, or fails or refuses to deliver to the Association for sale the pledged products, shall pay to the Association as liquidating damages, the sum of fifty cents for each gallon of syrup or the equivalent of a gallon of syrup in sap or sugar, not delivered by him, said sum may be deducted from any money in the possession of the Association due the member.

SEC. 3. This Association shall install a standard system of accounts, and provide other accounting appurtenances that may be necessary to conduct the business in safe and orderly manner.

SEC. 4. The books and business of the Association shall be audited annually by the auditors selected from the membership. A complete annual audit shall be made by a competent accountant previous to the date of each annual meeting, at which meeting his report shall be presented in full. Special audits shall be made upon order of the Board of Directors or upon a majority vote of the members at any regular or called meeting.

Sec. 5. This Association shall endeavor to cooperate with other farmers' cooperative associations in this locality in securing the services of a competent accountant for its annual audit.

### ARTICLE XIV.—*Amendments*

Section 1. These by-laws may be altered, amended, or repealed at any corporate meeting by the affirmative vote of two-thirds of the members present, provided that notice of such proposed alteration, amendment or repeal is included in the call for said meeting.

TABLE 1.—PRODUCTION OF MAPLE SUGAR AND SYRUP IN VERMONT, 1889, 1899, 1909 AND 1919. UNITED STATES CENSUS REPORTS

| | 1889 | | 1899 | | 1909 | | 1919 | |
|---|---|---|---|---|---|---|---|---|
| County | Pounds sugar | Gallons syrup | Pounds sugar | Gallons syrup | Pounds sugar | Gallons syrup | Pounds sugar | Gallons syrup |
| Addison | 416,878 | 3,221 | 166,170 | 1,255 | 231,478 | 23,126 | 215,899 | 25,863 |
| Bennington | 247,371 | 24,467 | 69,850 | 20,564 | 42,615 | 35,706 | 15,146 | 40,135 |
| Caledonia | 1,685,764 | 10,434 | 580,140 | 2,279 | 978,863 | 13,646 | 872,417 | 16,412 |
| Chittenden | 738,350 | 11,102 | 277,560 | 14,378 | 225,766 | 47,536 | 153,615 | 61,326 |
| Essex | 323,146 | 738 | 113,570 | 2,625 | 159,002 | 8,846 | 101,326 | 10,194 |
| Franklin | 1,970,946 | 4,652 | 913,000 | 15,908 | 1,584,476 | 42,866 | 845,211 | 136,124 |
| Grand Isle | 10,935 | 144 | 1,020 | 30 | 2,755 | 694 | 2,409 | 147 |
| Lamoille | 1,265,106 | 3,494 | 470,210 | 4,460 | 835,286 | 20,148 | 853,440 | 14,632 |
| Orange | 1,175,145 | 12,813 | 197,240 | 6,007 | 448,492 | 18,787 | 478,284 | 41,285 |
| Orleans | 2,108,537 | 1,808 | 992,690 | 4,683 | 1,902,438 | 12,320 | 1,669,559 | 15,039 |
| Rutland | 499,677 | 39,252 | 129,020 | 24,463 | 152,615 | 57,921 | 86,492 | 83,190 |
| Washington | 1,760,310 | 21,002 | 373,240 | 6,034 | 645,860 | 16,601 | 617,718 | 24,846 |
| Windham | 821,947 | 66,363 | 277,310 | 49,588 | 226,713 | 74,168 | 71,055 | 86,498 |
| Windsor | 1,099,809 | 18,762 | 218,850 | 8,644 | 290,458 | 37,588 | 269,163 | 76,233 |
| Total for State | 14,123,921 | 218,252 | 4,779,870 | 160,918 | 7,726,817 | 409,953 | 6,251,734 | 631,924 |

TABLE 2.[1]—MAPLE SUGAR AND SYRUP PRODUCTION IN 13 STATES, 1920, 1919, 1918 AND 1909

| State and year | Trees tapped | Sugar made | Syrup made | Average per tree | |
|---|---|---|---|---|---|
| | | | | As sugar | As syrup |
| | Number | Pounds | Gallons | Pounds | Gallons |
| Maine: | | | | | |
| 1920 ....... | 320,000 | 35,840 | 59,520 | 1.6 | 0.20 |
| 1919 ....... | 304,000 | 63,232 | 41,496 | 1.3 | .16 |
| 1918 ....... | 290,000 | 46,400 | 52,200 | 1.6 | .20 |
| 1909 ....... | 252,764 | 15,388 | 43,971 | 1.45 | .18 |
| New Hampshire: | | | | | |
| 1920 ....... | 930,000 | 334,800 | 167,400 | 1.8 | .22 |
| 1919 ....... | 870,000 | 445,440 | 118,320 | 1.6 | .20 |
| 1918 ....... | 870,000 | 556,800 | 147,900 | 2.0 | .25 |
| 1909 ....... | 792,147 | 558,811 | 111,500 | 1.83 | .23 |
| Vermont: | | | | | |
| 1920 ....... | 5,665,000 | 3,965,000 | 900,000 | 2.0 | .25 |
| 1919 ....... | 5,665,000 | 4,894,560 | 521,180 | 1.6 | .20 |
| 1918 ....... | 5,500,000 | 6,236,000 | 664,100 | 2.10 | .26 |
| 1909 ....... | 5,585,632 | 7,726,817 | 409,953 | 1.98 | .25 |

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[1] Figures for 1909 are from the United States census; all others are based upon reports from field agents and correspondents of the Bureau of Crop Estimates.

TABLE 2.—MAPLE SUGAR AND SYRUP PRODUCTION IN 13 STATES, 1920, 1919, 1918 AND 1909—*Concluded*

| State and year | Trees tapped | Sugar made | Syrup made | Average per tree |  |
|---|---|---|---|---|---|
|  |  |  |  | As sugar | As syrup |
|  | Number | Pounds | Gallons | Pounds | Gallons |
| Massachusetts: |  |  |  |  |  |
| 1920 ....... | 309,500 | 158,700 | 53,535 | 1.9 | .25 |
| 1919 ....... | 273,900 | 138,045 | 44,374 | 1.8 | .23 |
| 1918 ....... | 273,900 | 182,600 | 50,800 | 2.15 | .27 |
| 1909 ....... | 256,501 | 156,952 | 53,091 | 2.27 | .28 |
| Connecticut: |  |  |  |  |  |
| 1920 ....... | 15,525 | 4,600 | 5,000 | 2.9 | .35 |
| 1919 ....... | 13,500 | 5,832 | 2,308 | 1.8 | .22 |
| 1918 ....... | 13,500 | 8,900 | 3,900 | 3.0 | .38 |
| 1909 ....... | 12,296 | 10,207 | 4,236 | 3.65 | .46 |
| New York: |  |  |  |  |  |
| 1920 ....... | 6,122,000 | 2,204,000 | 1,255,000 | 2.0 | .25 |
| 1919 ....... | 6,062,000 | 3,161,000 | 1,401,000 | 2.37 | .30 |
| 1918 ....... | 6,236,000 | 3,732,000 | 1,755,000 | 2.85 | .35 |
| 1909 ....... | 4,948,784 | 3,160,300 | 993,242 | 2.24 | .28 |
| Pennsylvania: |  |  |  |  |  |
| 1920 ....... | 1,300,000 | 508,300 | 310,200 | 2.3 | .29 |
| 1919 ....... | 1,244,000 | 686,800 | 318,800 | 2.6 | .33 |
| 1918 ....... | 1,220,000 | 993,000 | 440,000 | 3.7 | .46 |
| 1909 ....... | 1,298,005 | 1,188,049 | 391,242 | 3.33 | .42 |
| Maryland: |  |  |  |  |  |
| 1920 ....... | 76,300 | 119,000 | 10,000 | 2.6 | .30 |
| 1919 ....... | 76,300 | 221,300 | 20,000 | 5.0 | .62 |
| 1918 ....... | 74,800 | 179,500 | 15,000 | 4.0 | .50 |
| 1909 ....... | 79,658 | 351,908 | 12,172 | 5.64 | .70 |
| West Virginia: |  |  |  |  |  |
| 1920 ....... | 60,000 | 86,000 | 16,000 | 3.6 | .45 |
| 1919 ....... | 100,000 | 160,000 | 30,000 | 4.0 | .50 |
| 1918 ....... | 105,000 | 147,000 | 27,500 | 3.5 | .44 |
| 1909 ....... | 97,274 | 140,060 | 31,176 | 4.0 | .50 |
| Ohio: |  |  |  |  |  |
| 1920 ....... | 2,230,000 | 41,600 | 427,400 | 1.6 | .20 |
| 1919 ....... | 2,350,000 | 110,320 | 752,310 | 2.6 | .35 |
| 1918 ....... | 2,660,000 | 558,600 | 1,093,900 | 3.5 | .44 |
| 1909 ....... | 3,170,828 | 257,592 | 1,323,431 | 3.42 | .43 |
| Indiana: |  |  |  |  |  |
| 1920 ....... | 695,000 | 6,000 | 125,000 | 1.4 | .18 |
| 1919 ....... | 700,000 | 200,000 | 273,000 | 3.4 | .43 |
| 1918 ....... | 700,000 | 283,000 | 267,800 | 3.4 | .42 |
| 1909 ....... | 742,586 | 33,419 | 273,728 | 2.99 | .37 |
| Michigan: |  |  |  |  |  |
| 1920 ....... | 848,000 | 47,100 | 190,200 | 1.8 | .22 |
| 1919 ....... | 874,000 | 57,700 | 233,100 | 2.2 | .28 |
| 1918 ....... | 930,000 | 364,600 | 279,900 | 2.8 | .35 |
| 1909 ....... | 986,737 | 293,301 | 269,093 | 2.48 | .31 |
| Wisconsin: |  |  |  |  |  |
| 1920 ....... | 460,000 | 17,700 | 86,300 | 1.54 | .19 |
| 1919 ....... | 442,000 | 24,400 | 98,600 | 1.84 | .22 |
| 1918 ....... | 425,000 | 26,500 | 107,200 | 2.08 | .26 |
| 1909 ....... | 449,727 | 27,199 | 124,117 | 2.26 | .28 |
| Total 13 States: |  |  |  |  |  |
| 1920 ....... | 19,031,325 | 7,528,640 | 3,605,555 | 1.91 | .24 |
| 1919 ....... | 18,974,700 | 10,168,629 | 3,854,488 | 2.16 | .27 |
| 1918 ....... | 19,298,200 | 13,270,900 | 4,905,200 | 2.72 | .35 |
| 1909 ....... | 18,672,939 | 13,920,003 | 4,040,952 | 2.48 | .31 |

TABLE 3.[1]—PRODUCTION OF MAPLE SYRUP AND SUGAR IN THE UNITED STATES, 1859 TO 1921

| Year | Sugar made<br>Pounds | Syrup made<br>Gallons | Total as sugar[2]<br>Pounds |
|---|---|---|---|
| 1859 ............... | 40,120,205 | 1,597,589 | 52,900,917 |
| 1869 ............... | 28,443,645 | 921,057 | 35,812,101 |
| 1879 ............... | 36,756,061 | 1,796,048 | 51,124,445 |
| 1889 ............... | 32,952,927 | 2,258,376 | 51,019,935 |
| 1899 ............... | 11,928,770 | 2,056,611 | 28,381,658 |
| 1909 ............... | 14,060,206 | 4,106,418 | 46,911,550 |
| 1917 ............... | 10,838,650 | 4,286,100 | 45,127,450 |
| 1918 ............... | 13,270,865 | 4,905,264 | 52,512,977 |
| 1919 ............... | 10,168,629 | 3,854,488 | 41,004,533 |
| 1920 ............... | 7,555,040 | 3,657,255 | 36,813,080 |
| 1921 ............... | 5,093,100 | 2,583,500 | 25,761,100 |

TABLE 4.—IMPORTS OF MAPLE SUGAR AND SYRUP, 1914 TO 1920[3]

| | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 | 1920 |
|---|---|---|---|---|---|---|---|
| Pounds | 1,870,961 | 1,714,833 | 2,677,280 | 3,456,756 | 4,135,067 | 3,928,301 | 8,337,859 |
| Value | $153,191 | $171,700 | $286,525 | $495,382 | $875,201 | $1,109,666 | $1,974,977 |

TABLE 5.—FARM VALUE OF MAPLE SUGAR (CENTS PER POUND), 1917 TO 1921

| | | 1917 | 1918 | 1919 | 1920 | 1921 |
|---|---|---|---|---|---|---|
| Vermont | Feb. 15 | 15.0 | 19.5 | 23.5 | 30.0 | 23.0 |
| | Mar. 15 | 13.0 | 20.0 | 27.0 | 32.0 | 24.0 |
| | Apr. 15 | 15.0 | 22.0 | 29.0 | 36.0 | 22.0 |
| | May 15 | 14.6 | 22.0 | 26.0 | 34.0 | 17.0 |
| | June 15 | 15.4 | 22.0 | 26.0 | 33.0 | 16.0 |
| New York | Feb. 15 | 14.0 | 17.8 | 20.5 | 27.0 | 28.0 |
| | Mar. 15 | 15.0 | 20.0 | 23.0 | 29.0 | 25.0 |
| | Apr. 15 | 16.5 | 22.0 | 25.0 | 37.0 | 27.0 |
| | May 15 | 16.5 | 22.0 | 26.0 | 37.0 | 22.0 |
| | June 15 | 15.8 | 21.0 | 26.0 | 37.0 | 23.0 |
| Ohio | Feb. 15 | 15.5 | 20.0 | 18.0 | 25.0 | 20.0 |
| | Mar. 15 | 16.0 | 23.0 | 25.0 | 30.0 | 24.0 |
| | Apr. 15 | 17.5 | 23.0 | 28.0 | 39.0 | 26.0 |
| | May 15 | 19.2 | 24.0 | 27.0 | 42.0 | 30.0 |
| | June 15 | 18.3 | 25.0 | 27.0 | 38.0 | 23.0 |
| Wisconsin | Feb. 15 | 15.0 | 20.4 | 27.0 | 35.0 | 40.0 |
| | Mar. 15 | 16.0 | 21.0 | 25.0 | 32.0 | 33.0 |
| | Apr. 15 | 20.0 | 25.0 | 34.0 | 32.0 | 30.0 |
| | May 15 | 19.0 | 25.0 | 36.0 | 40.0 | 32.0 |
| | June 15 | 16.8 | 23.0 | 34.0 | ... | 34.0 |
| United States | Feb. 15 | 14.7 | 18.8 | 22.0 | 29.3 | 24.9 |
| | Mar. 15 | 14.7 | 20.5 | 25.3 | 31.6 | 25.7 |
| | Apr. 15 | 16.3 | 22.5 | 26.9 | 37.0 | 25.7 |
| | May 15 | 16.2 | 22.6 | 26.3 | 36.0 | 21.5 |
| | June 15 | 15.9 | 22.0 | 26.2 | 35.1 | 20.7 |

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[1] Figures given for the period 1917 to 1921 are from reports of the Bureau of Markets and Crop Estimates covering the 13 states represented in table 2. Figures for other years are from the census reports.

[2] A gallon of syrup is considered the equivalent of eight pounds of sugar.

[3] Statistical Abstract of the United States, 1920.

TABLE 6.—FARM VALUE OF MAPLE SYRUP (DOLLARS PER GALLON), 1917 TO 1921

| | | 1917 | 1918 | 1919 | 1920 | 1921 |
|---|---|---|---|---|---|---|
| Vermont | Feb. 15 | $1.20 | $1.70 | $2.10 | $2.70 | $2.03 |
| | Mar. 15 | 1.20 | 1.75 | 2.20 | 2.70 | 1.93 |
| | Apr. 15 | 1.25 | 1.90 | 2.00 | 2.85 | 1.80 |
| | May 15 | 1.30 | 2.00 | 1.95 | 2.70 | 1.32 |
| | June 15 | 1.30 | 1.75 | 2.10 | 2.70 | 1.40 |
| New York | Feb. 15 | 1.15 | 1.50 | 1.75 | 2.30 | 2.15 |
| | Mar. 15 | 1.25 | 1.60 | 1.80 | 2.45 | 2.10 |
| | Apr. 15 | 1.30 | 1.75 | 2.00 | 2.90 | 2.15 |
| | May 15 | 1.30 | 1.75 | 2.00 | 2.90 | 1.91 |
| | June 15 | 1.30 | 1.70 | 1.90 | 2.90 | 1.90 |
| Ohio | Feb. 15 | 1.25 | 1.50 | 1.90 | 2.40 | 2.35 |
| | Mar. 15 | 1.30 | 1.75 | 2.00 | 2.55 | 2.11 |
| | Apr. 15 | 1.30 | 1.75 | 2.00 | 2.95 | 2.22 |
| | May 15 | 1.30 | 1.80 | 2.00 | 3.00 | 2.13 |
| | June 15 | 1.30 | 1.90 | 2.40 | 2.80 | 2.20 |
| Wisconsin | Feb. 15 | 1.30 | 1.80 | 1.80 | 2.30 | 2.80 |
| | Mar. 15 | 1.30 | 1.65 | 1.80 | 2.20 | 2.45 |
| | Apr. 15 | 1.50 | 1.95 | 2.10 | 2.75 | 2.55 |
| | May 15 | 1.53 | 1.90 | 2.40 | 2.90 | 2.52 |
| | June 15 | 1.60 | 1.95 | 2.20 | 2.90 | 2.50 |
| United States | Feb. 15 | 1.22 | 1.58 | 1.86 | 2.35 | 2.27 |
| | Mar. 15 | 1.30 | 1.76 | 1.99 | 2.58 | 2.17 |
| | Apr. 15 | 1.33 | 1.80 | 2.03 | 2.92 | 2.21 |
| | May 15 | 1.34 | 1.85 | 2.02 | 2.93 | 2.08 |
| | June 15 | 1.33 | 1.85 | 2.19 | 2.84 | 2.10 |

TABLE 7.—PER CAPITA CONSUMPTION OF SUGAR IN THE UNITED STATES, 1865 TO 1920[1]

| Year | Pounds | Year | Pounds | Year | Pounds |
|---|---|---|---|---|---|
| 1865 | 18.17 | 1884 | 54.18 | 1903 | 78.84 |
| 1866 | 28.45 | 1885 | 47.87 | 1904 | 68.54 |
| 1867 | 24.30 | 1886 | 49.09 | 1905 | 71 55 |
| 1868 | 31.24 | 1887 | 53.26 | 1906 | 75.62 |
| 1869 | 35.19 | 1888 | 50.29 | 1907 | 81.08 |
| 1870 | 32.73 | 1889 | 50.44 | 1908 | 73.99 |
| 1871 | 36.47 | 1890 | 50.63 | 1909 | 80.31 |
| 1872 | 40.64 | 1891 | 60.21 | 1910 | 79.77 |
| 1873 | 40.08 | 1892 | 59.69 | 1911 | 77.24 |
| 1874 | 41.64 | 1893 | 63.65 | 1912 | 82.67 |
| 1875 | 43.33 | 1894 | 72.30 | 1913 | 85.32 |
| 1876 | 35.42 | 1895 | 62.11 | 1914 | 89.80 |
| 1877 | 39.07 | 1896 | 63.41 | 1915 | 86.84 |
| 1878 | 34.59 | 1897 | 77.55 | 1916 | 79.00 |
| 1879 | 40.99 | 1898 | 47.20 | 1917 | 82.87 |
| 1880 | 39.46 | 1899 | 61.56 | 1918 | 78.06 |
| 1881 | 42.89 | 1900 | 58.81 | 1919 | 83.55 |
| 1882 | 40.82 | 1901 | 71.84 | 1920 | 91.46 |
| 1883 | 45.20 | 1902 | 63.24 | | |

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[1] Statistical Abstract of the United States, 1920.

TABLE 8.—RANGE OF RETAIL PRICES PER POUND FOR SIX CLASSES OF SYRUP, FOUND IN 25 MODERATE PRICED GROCERY STORES, PHILADELPHIA, MARCH, 1922

| Syrup | Price per pound |
|---|---|
| Class A (Maple) | 36 to 60 cts. |
| Class B (Cane and maple blend) | 25 to 38 cts. |
| Class C (Corn and maple blend) | 28 cts. |
| Class D (Corn syrup) | 6 to 12 cts. |
| Class E (Corn "cooking syrup") | 5 to 7 cts. |

TABLE 9.—RATES ON MAPLE SYRUP IN METAL CANS OR PAILS IN BOXES, AND MAPLE SUGAR IN PACKAGES FROM ESSEX JUNCTION, VERMONT, TO VARIOUS MARKETS. RATES ARE IN CENTS PER 100 POUNDS FOR CAR LOT (C. L.) AND LESS THAN CAR LOT (L. C. L.) SHIPMENTS

| From Essex Junction, Vt. To | Maple Syrup C. L cts. | Maple Syrup L. C. L. cts. | Maple Sugar C. L. cts. | Maple Sugar L. C. L. cts. |
|---|---|---|---|---|
| Atlanta, Ga. | 126 | 126 | 126 | 179½ |
| Baltimore, Md. | 40½ | 53 | 47 | 66 |
| Boston, Mass. | 34 | 52 | 48½ | 65 |
| Buffalo, N. Y. | 40½ | 53 | 47 | 66 |
| Butte, Mont. | 183½ | 327½ | 248 | 407½ |
| Chicago, Ill. | 59 | 79 | 69½ | 99 |
| Cincinnati, Ohio | 51 | 68½ | 60 | 85½ |
| Cleveland, Ohio | 44½ | 59½ | 52 | 74½ |
| Dallas, Tex. | 144 | 255½ | 236 | 292½ |
| Denver, Colo. | 152 | 223 | 213½ | 284½ |
| Detroit, Mich. | 46 | 62½ | 54½ | 78 |
| El Paso, Tex. | 183½ | 296 | 284½ | 353½ |
| Fort Worth, Tex. | 144 | 255½ | 236 | 292½ |
| Jacksonville, Fla. | 118½ | 118½ | 118½ | 169 |
| Kansas City, Mo. | 99 | 133 | 123½ | 175½ |
| Little Rock, Ark. | 154½ | 200 | 188½ | 241 |
| Los Angeles, Cal. | 183½ | 375 | 261½ | 442 |
| Memphis, Tenn. | 133½ | 133½ | 133½ | 191 |
| Milwaukee, Wis. | 59 | 79 | 69½ | 99 |
| Mobile, Ala. | 143 | 143 | 143 | 205 |
| New Orleans, La. | 143 | 143 | 143 | 205 |
| New York, N. Y. | 39 | 53 | 47 | 66 |
| Omaha, Neb. | 99 | 133 | 123½ | 175½ |
| Philadelphia, Pa. | 40½ | 53 | 47 | 66 |
| Pittsburgh, Pa. | 40½ | 53 | 47 | 66 |
| Portland, Ore. | 183½ | 375½ | 208½ | 442 |
| Richmond, Va. | 63 | 76 | 74 | 95 |
| St. Louis, Mo. | 69½ | 93½ | 82 | 117 |
| St. Paul, Minn. | 82½ | 110 | 69 | 137½ |
| Salt Lake City, Utah | 183½ | 318½ | 208½ | 333½ |
| San Antonio, Tex. | 153½ | 255½ | 248½ | 295 |
| San Diego, Cal. | 183½ | 375½ | 261½ | 442 |
| San Francisco, Cal. | 183½ | 375½ | 261½ | 442 |
| Savannah, Ga. | 118½ | 118½ | 118½ | 169 |
| Seattle, Wash. | 183½ | 375½ | 208½ | 442 |
| Spokane, Wash. | 183½ | 333½ | 208½ | 415½ |
| Washington, D. C. | 52½ | 67½ | 63 | 84½ |

SEPTEMBER, 1922 BULLETIN 228

University of Vermont and State Agricultural College

# Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# COMMERCIAL FERTILIZERS
# COMMERCIAL FEEDING STUFFS
# AGRICULTURAL SEED

BURLINGTON
Free Press Printing Company
1922

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Director's office, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place. University farm and buildings are on the Williston road, adjoining the University campus on the east.

# BULLETIN 228: COMMERCIAL FERTILIZERS, COMMERCIAL FEEDING STUFFS, AGRICULTURAL SEED

By J. L. Hills, C. H. Jones, G. F. Anderson, Anna S. Lutman

The results of the police work performed during 1922 by the Station in accordance with state laws is set forth in condensed form in this bulletin. The Station regrets its inability to furnish the full information which has been vouchsafed prior to 1919.

It may be said in brief:

*Fertilizer Control.* That the fertilizers sold in 1922, as a whole, were quite as good as they were represented to be.—Pages 3-15.

*Feeding Stuffs Inspection.* That the results were normal, only 3 percent of the brands being deficient and only one brand in 294 seriously so.—Pages 15-22.

*Agricultural Seed Inspection.* That one lot in 20 was not guaranteed and one in 30 seriously deficient in respect to the maintenance of the purity guaranty.—Pages 22-32.

## FERTILIZER CONTROL

The last General Assembly amended and extended the fertilizer law to cover fertilizer crude stocks and limes. As a consequence, the total number of brands licensed leaped upwards as compared with former years, being in 1921, 153, and in 1922, 228. The licenses of the current year cover: complete fertilizers, 153; incomplete fertilizers (i. e., compounded goods carrying only either nitrogen and available phosphoric acid or available phosphoric acid and potash only), 6; crude stocks, 58; limes, 11. The number of brands sampled and analyzed increased from 137 to 203, a gain of almost exactly 50 percent.

The sampling agents of the State visited 103 Vermont cities, towns and villages in the spring and early summer of 1922 and drew 617 samples from dealers' stocks representing 203 of the 228 brands of commercial fertilizers licensed for sale. No samples of 25 brands named below were secured. In several instances no sales were made.

**American Agricultural Chemical Company's Dry Ground Fish.**
**American Agricultural Chemical Company's Patapsco Four-Eight-Seven.**
**American Agricultural Chemical Company's Williams & Clark's Americus Ammoniated Bone Superphosphate.**
**American Agricultural Chemical Company's Williams & Clark's Americus High Grade Special for Potatoes and Vegetables.**
**Armour Fertilizer Company's Big Crop Five-Eight-Five.**
**Armour Fertilizer Company's Big Crop Four-Ten.**
**Bowker Fertilizer Company's Maryland Truck Garden.**
**Brewer & Company's Producto Agricultural Lime.**

**Consolidated Rendering Company's Ground Bone (3/50).**
**Cooperative Potato Exchange, Inc., Acid Phosphate.**
**Cooperative Potato Exchange, Inc., Muriate of Potash.**
**Cooperative Potato Exchange, Inc., Nitrate of Soda.**
**Dominion Lime Company's Ground Limestone.**
**Eastern States Farmers' Exchange's Dry Ground Fish.**
**Eastern States Farmers' Exchange's Ground Bone 3/50.**
**Eastern States Farmers' Exchange's Ground Bone 4½/45.**
**Empire Guano Company's Acid Phosphate.**
**Miller Fertilizer Company's Acid Phosphate.**
**Parmenter & Polsey Fertilizer Company's Four-Eight-Four.**
**Parmenter & Polsey Fertilizer Company's Three-Eight-Three.**
**Reading Bone Fertilizer Company's Dissolved Animal Matter.**
**Reading Bone Fertilizer Company's Pure Raw Bone.**
**Rockland-Rockport Lime Corporation's R. R. Ground Lime.**
**Rockland-Rockport Lime Corporation's R. R. Ground Limestone.**
**Sanderson Fertilizer & Chemical Company's Atlantic Coast Bone, Fish and Potash.**

The condensed statements on pages 5 to 10 set forth the essential facts as to the maintenance of guaranties. The order of statement is alphabetical by names of manufacturers.

The first four figures in the table, reading horizontally following the brand name, indicate what the manufacturers' promises were, expressed in percentage terms; and the word following, usually "Yes", rarely "No", tells in this laconic, straightforward fashion whether or not the promises have been kept.

The next two figures show the quality of the nitrogen purveyed by the manufacturer, indicating in terms of decimals the proportions of the total nitrogen present in water-soluble and water-insoluble forms. The former includes nitrate nitrogen, ammoniacal nitrogen and such organic nitrogen as is water-soluble; the latter such organic nitrogen as is not soluble in water, more or less of which—more in some cases, less in others—is available to plant growth.

The last figure, reading horizontally, indicates in terms of a decimal what proportion of the total phosphoric acid is furnished in available form.

The last column shows by the presence of the letter C or S as the case may be whether the potash, if present, was present as muriate or chlorid (C) or as sulphate (S). In case both were present, the letters CS or SC are used, the one first given indicating predominance.

The statement concerning the quality of organic nitrogen heretofore included is omitted for the reason that every fertilizer save one qualified, that is to say, no indication was found of the presence of material quantities of unavailable nitrogen.

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | Water-soluble | Water-insoluble | | |
| **American Agricultural Chemical Company, 92 State St., Boston, Mass.** | | | | | | | | | |
| Complete Manure with 10% Potash | 3.29 | 7 | 6 | 10 | Yes | .8 | .2 | .9 | C |
| Complete Potato Mixture | 2.47 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Grass and Lawn Top Dressing | 4.94 | 7 | 6 | 4 | Yes | .9 | .1 | .9 | C |
| Grass and Oats Fertilizer | ... | 13 | 12 | 2 | Yes | .. | .. | .8 | C |
| Ground Bone | 2.08 | 22.86 | .. | .. | Yes | .0 | 1.0 | * | .. |
| High Grade Acid Phosphate | ... | 17 | 16 | .. | Yes | .. | .. | .9 | .. |
| Monarch Potato Manure | 3.29 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Muriate of Potash | ... | .. | .. | 48 | Yes | .. | .. | .. | C |
| Nitrate of Soda | 15 | .. | .. | .. | Yes | 1.0 | .0 | .. | .. |
| Patapsco Acid Phosphate | ... | 17 | 16 | .. | Yes | .0 | .0 | .9 | .. |
| Patapsco General Truck Fertilizer | 2.47 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Patapsco Matchless Potash Manure | 1.65 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| Patapsco Money Maker | 0.82 | 9 | 8 | 2 | Yes | .5 | .5 | .9 | C |
| Patapsco Peerless Potato Guano | 3.29 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Patapsco 3/9/2 | 2.47 | 10 | 9 | 2 | Yes | .8 | .2 | .8 | CS |
| Peerless Potato Manure | 3.29 | 9 | 8 | 7 | Yes | .8 | .2 | .9 | C |
| Two-Eight-Six Fertilizer | 1.65 | 9 | 8 | 6 | Yes | .8 | .2 | .9 | C |
| Universal Phosphate | 0.82 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| *(Bradley Fertilizer Company Brands).* | | | | | | | | | |
| Complete Manure for Potatoes and Vegetables | 3.29 | 9 | 8 | 7 | Yes | .8 | .2 | .9 | C |
| Complete Manure for Top Dressing Grass and Grain | 4.94 | 7 | 6 | 4 | Yes | .9 | .1 | .9 | C |
| Complete Manure with 10% Potash | 3.29 | 7 | 6 | 10 | Yes | .8 | .2 | .9 | C |
| Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| Eclipse Phosphate | 0.82 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| Northland Potato Grower | 3.29 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Potato Fertilizer | 1.65 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | C |
| Potato Manure | 2.47 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| XL Superphosphate of Lime | 2.47 | 10 | 9 | 2 | Yes | .8 | .2 | .8 | SC |
| *(Crocker Fertilizer & Chemical Company Brands)* | | | | | | | | | |
| Ammoniated Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| New Rival Ammoniated Superphos. | 0.82 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| Potato, Hop and Tobacco Fertilizer | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| *(Great Eastern Fertilizer Company Brands)* | | | | | | | | | |
| General | 0.82 | 9 | 8 | 2 | Yes | .7 | .3 | .8 | C |
| Northern Corn Special | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .8 | C |
| Potato Manure | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| *(Listers' Agricultural Chemical Works Brands)* | | | | | | | | | |
| Corn and Potato Fertilizer | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| Four-Eight-Four Fertilizer | 3.29 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| Grain and Grass Fertilizer | ... | 13 | 12 | 2 | Yes | .0 | .0 | .9 | C |
| Success Fertilizer | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |

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*Not determined.

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | Water-soluble | Water-insoluble | | |
| *(Pacific Guano Company Brands)* | | | | | | | | | |
| Pacific Potato Special | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| Soluble Pacific Guano | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| *(Quinnipiac Company Brands)* | | | | | | | | | |
| Corn Manure | 1.65 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| Market Garden Manure | 3.29 | 9 | 8 | 7 | Yes | .8 | .2 | .9 | C |
| Potato Phosphate | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| *(Read Fertilizer Company Brands)* | | | | | | | | | |
| Farmers' Friend Superphosphate | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| Practical Potato Special Fertilizer | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| *(Williams & Clark Fertilizer Company Brands)* | | | | | | | | | |
| Americus Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| Americus Potato Manure | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| Potato Phosphate | 2.47 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| **Armour Fertilizer Works, 1501-1514 Munsey Building, Baltimore, Md.** | | | | | | | | | |
| Big Crop Acid Phosphate | ... | 16.5 | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| Big Crop Potato and Onion 4/8/4 | 3.29 | 8.5 | 8 | 4 | Yes | .8 | .2 | 1.0 | C |
| Big Crop Fertilizer 3/8/4 | 2.47 | 8.5 | 8 | 4 | No | .8 | .2 | 1.0 | C |
| Big Crop Fertilizer 2/10/6 | 1.65 | 10.5 | 10 | 6 | Yes | .7 | .3 | 1.0 | C |
| Bone Meal | 2.47 | 22 | .. | .. | Yes | .0 | 1.0 | .0 | .. |
| Corn Grower 2/8/2 | 1.65 | 8.5 | 8 | 2 | Yes | .7 | .3 | 1.0 | C |
| General Crop Fertilizer 1/7/1 | 0.82 | 7.5 | 7 | 1 | Yes | .7 | .3 | .9 | C |
| Sheep Manure | 1.23 | 1 | .. | 2.5 | Yes | .. | .. | .. | .. |
| **Atlantic Packing Co., 40 North Market St., Boston, Mass.** | | | | | | | | | |
| Four-Eight-Four | 3.28 | 9 | 8 | 4 | Yes | .7 | .3 | .8 | C |
| Four-Eight-Seven | 3.28 | 9 | 8 | 7 | Yes | .7 | .3 | .9 | C |
| Three-Eight-Four | 2.47 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| **Bowker Fertilizer Company, 43 Chatham Street, Boston, Mass.** | | | | | | | | | |
| Acid Phosphate (16%) | ... | .. | 16 | .. | Yes | .. | .. | 1.0 | .. |
| All Round Fertilizer | 2.47 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| Corn, Grain and Grass Phosphate | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |
| Early Potato Manure | 3.29 | 9 | 8 | 7 | Yes | .9 | .1 | .9 | C |
| Hill and Drill Phosphate | 2.47 | 10 | 9 | 2 | No | .8 | .2 | .9 | C |
| Stockbridge Potato and Vegetable Manure | 3.29 | 7 | 6 | 10 | Yes | .8 | .2 | .9 | C |
| Potato and Vegetable Phosphate | 1.65 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | SC |
| Maryland Acid Phosphate | ... | .. | 16 | .. | Yes | .. | .. | 1.0 | .. |
| Maryland Corn Phosphate | 1.65 | 9 | 8 | 2 | Yes | .8 | .2 | .8 | C |
| Maryland One-Eight-Two | 0.82 | 9 | 8 | 2 | Yes | .8 | .2 | 1.0 | C |
| Stockbridge Early Crop Manure | 4.11 | 9 | 8 | 7 | Yes | .8 | .2 | .9 | C |
| Stockbridge Market Garden Manure | 3.29 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Stockbridge Top Dressing and Forcing Manure | 4.92 | 7 | 6 | 4 | Yes | .9 | .1 | .9 | C |
| Sure Crop Phosphate | 0.82 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |

## CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | Water-soluble | Water-insoluble | | |
| **Joseph Breck & Sons Corporation, 51 North Market St., Boston, Mass.** | | | | | | | | | |
| Breck's Ram's Head Brand Sheep Manure | See special statement page 12. | | | | | | | | |
| **Burlington Rendering Company, North Ave., Burlington, Vt.** | | | | | | | | | |
| Five-Eight-Four | 4.11 | 9 | 8 | 4 | Yes | .8 | .2 | 1.0 | C |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | .6 | .4 | .9 | C |
| Four-Eight-Seven | 3.29 | 9 | 8 | 7 | Yes | .7 | .3 | .9 | C |
| Three-Eight-Four | 2.47 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Three | 1.65 | 9 | 8 | 3 | Yes | .7 | .3 | 1.0 | C |
| Two-Eight-Two | 1.65 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| **Chamberlin & Barclay, Cranbury, N. J.** | | | | | | | | | |
| Standard Four-Eight-Seven | 3.3 | 9 | 8 | 7 | Yes | .7 | .3 | .9 | C |
| **Coe-Mortimer Company, Merchants Row and South Market St., Boston, Mass.** | | | | | | | | | |
| Celebrated Special Potato Fertilizer | 3.29 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Columbian Corn and Potato Fert. | 1.65 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| Corn King | 2.47 | 10 | 9 | 2 | Yes | .8 | .2 | .8 | C |
| Gold Brand Excelsior Guano | 2.47 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| New Englander Special | 0.82 | 9 | 8 | 2 | Yes | .5 | .5 | .9 | C |
| Red Brand Excelsior Guano | 3.29 | 9 | 8 | 7 | Yes | .9 | .1 | .9 | C |
| Special Grass Topdressing | 4.94 | 7 | 6 | 4 | Yes | .9 | .1 | .8 | C |
| Standard Potato Fertilizer | 3.29 | 7 | 6 | 10 | Yes | .8 | .2 | .8 | C |
| Superphosphate (16%) | ... | 17 | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| **Consolidated Rendering Company, 40 North Market St., Boston, Mass.** | | | | | | | | | |
| Acid Phosphate | ... | 17 | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| Ground Bone | 2.46 | 24 | .. | .. | Yes | .. | .. | .. | .. |
| Ground Bone | 2.05 | 26 | .. | .. | Yes | .. | .. | .. | .. |
| Muriate of Potash | ... | .. | .. | 50 | Yes | .. | .. | .. | C |
| Nitrate of Soda | 15.5 | .. | .. | .. | No | 1.0 | .0 | .. | .. |
| Sulphate of Ammonia | 20.5 | .. | .. | .. | Yes | 1.0 | .0 | .. | .. |
| Tankage 9/20 | 7.41 | 10 | .. | .. | Yes | .3 | .7 | .. | .. |
| Tankage 6/30 | 4.92 | 14 | .. | .. | Yes | .4 | .6 | .. | .. |
| **Darling & Co., Ashland Ave. and 42nd St., Union Stock Yards, Chicago, Ill.** | | | | | | | | | |
| Pulverized Sheep Manure | 2.06 | 1 | .. | 1 | Yes | * | * | * | * |
| **Earp-Thomas Cultures Corporation, 80 Lafayette St., New York** | | | | | | | | | |
| Stim-U PlanT | 11 | .. | 12 | 15 | No | 1.0 | .0 | 1.0 | CS |
| **Eastern States Farmers' Exchange, 292 Worthington St., Springfield, Mass.** | | | | | | | | | |
| Acid Phosphate (16%) | ... | .. | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| Five-Eight-Five | 4.11 | 9 | 8 | 5 | Yes | .8 | .2 | .8 | C |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| Four-Eight-Seven | 3.29 | 9 | 8 | 7 | Yes | .8 | .2 | .8 | C |
| Four-Ten | 3.29 | .. | 10 | .. | Yes | .8 | .2 | .9 | .. |
| Muriate of Potash | ... | .. | .. | 48 | Yes | .. | .. | .. | C |
| Nitrate of Soda | 14.75 | .. | .. | .. | Yes | 1.0 | .0 | .. | .. |
| Sulphate of Ammonia | 20.5 | .. | .. | .. | Yes | 1.0 | .0 | .. | .. |
| Sulphate of Potash | ... | .. | .. | 50 | Yes | .. | .. | .. | S |
| Tankage | 5.75 | 6.9 | .. | .. | Yes | .2 | .8 | * | .. |
| Tankage | 8.2 | 4.6 | .. | .. | Yes | .2 | .8 | * | .. |
| Three-Eight-Four | 2.46 | 9 | 8 | 4 | Yes | .8 | .2 | .8 | C |
| Two-Eight-Two | 1.64 | 9 | 8 | 2 | Yes | .8 | .2 | .9 | C |

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*Not determined.

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | Water-soluble | Water-insoluble | | |
| **Essex Fertilizer Company, 39 North Market St., Boston, Mass.** | | | | | | | | | |
| Fish Fertilizer 3/8/3 for All Crops | 2.46 | 9 | 8 | 3 | Yes | .8 | .2 | .9 | C |
| Five-Eight-Four | 4.1 | 9 | 8 | 4 | Yes | .7 | .3 | .8 | C |
| Four-Eight-Four for Potatoes, Roots and Vegetables | 3.28 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| Market Garden 3/8/4 for Vegetables and Grass | 2.46 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| One-Ten-One for Grain and Grass | 0.82 | 11 | 10 | 1 | Yes | .6 | .4 | .9 | C |
| Three-Six-Ten for Corn, Potatoes and Vegetables | 2.46 | 7 | 6 | 10 | Yes | .7 | .3 | 1.0 | C |
| Tobacco Five-Five-Five | 4.1 | 6 | 5 | 5 | Yes | .6 | .4 | .6 | SC |
| Two-Eight-Six | 1.64 | 9 | 8 | 6 | Yes | .5 | .5 | .9 | C |
| Two-Eight-Two for Farm and Garden | 1.64 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Three for All Crops | 1.64 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | C |
| **International Agricultural Corporation**<br>**Buffalo Fertilizer Works, Buffalo, N. Y.** | | | | | | | | | |
| Acid Phosphate (16%) | ... | .. | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| Buffalo Economy | 1.65 | 9 | 8 | 2 | Yes | .6 | .4 | .8 | C |
| Buffalo Farmers' Choice | 0.82 | 9 | 8 | 4 | Yes | .6 | .4 | .9 | C |
| Buffalo High Grade Manure | 3.29 | 7 | 6 | 10 | Yes | .7 | .3 | .9 | C |
| Buffalo New England Special | 1.65 | 11 | 10 | 4 | Yes | .6 | .4 | .9 | C |
| Buffalo Nitrate of Soda | 15 | .. | .. | .. | Yes | 1.0 | .0 | .. | .. |
| Buffalo Phosphate and Potash | ... | 11 | 10 | 8 | Yes | .0 | .0 | 1.0 | C |
| Buffalo Vegetable and Potato 3 8 6 | 2.47 | 9 | 8 | 6 | Yes | .7 | .3 | .9 | C |
| **Lowell Fertilizer Company, 40 North Market St., Boston, Mass.** | | | | | | | | | |
| Animal Brand 3 8 4 for All Crops | 2.46 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Bone Fertilizer 2 8 2 for Corn, Grain, Grass and Vegetables | 1.64 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| Empress Brand 1 10 1 for Grain and Vegetables | 0.82 | 11 | 10 | 1 | Yes | .7 | .3 | .9 | C |
| Five-Eight-Four | 4.1 | 9 | 8 | 4 | Yes | .7 | .3 | .8 | C |
| Four-Eight-Four for Potatoes, Corn and Vegetables | 3.28 | 9 | 8 | 4 | Yes | .8 | .2 | .8 | C |
| Four-Eight-Six | 3.29 | 9 | 8 | 6 | Yes | .7 | .3 | .9 | C |
| Four-Six-Ten for Potatoes and Vegetables | 3.28 | 7 | 6 | 10 | Yes | .7 | .3 | .9 | C |
| Three-Eight-Three | 2.46 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | C |
| Three-Six-Ten for Corn, Potatoes and Vegetables | 2.46 | 7 | 6 | 10 | Yes | .6 | .4 | .9 | C |
| Two-Eight-Three for Vegetables and Grain | 1.64 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Six for Grain, Grass and Potatoes | 1.64 | 9 | 8 | 6 | Yes | .5 | .5 | .9 | C |

CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | Water-soluble | Water-insoluble | | |
| **New England Fertilizer Company, 40A North Market St., Boston, Mass.** | | | | | | | | | |
| Corn Phosphate 2/8/2 for Grain and Vegetables | 1.64 | 9 | 8 | 2 | Yes | .6 | .4 | .9 | C |
| Five-Eight-Seven for Potatoes and Market Garden | 4.1 | 9 | 8 | 7 | No | .7 | .3 | .8 | C |
| Four-Eight-Four for Potatoes, Vegetables and Grass | 3.28 | 9 | 8 | 4 | No | .7 | .3 | .9 | C |
| Four-Eight-Seven for Potatoes and Vegetables | 3.28 | 9 | 8 | 7 | Yes | .7 | .3 | .9 | C |
| Standard Phosphate 1/10/1 for Grain and Grass | 0.82 | 11 | 10 | 1 | Yes | .6 | .4 | .9 | C |
| Superphosphate 3/8/4 for All Crops | 2.46 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Three-Six-Ten for Corn, Potatoes and Vegetables | 2.46 | 7 | 6 | 10 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Three for Grain and Vegetables | 1.64 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Six for Grain, Grass and Potatoes | 1.64 | 9 | 8 | 6 | Yes | .5 | .5 | .9 | C |
| **Norwegian Nitrogen Products Co., Inc., 17 State St., New York, N. Y.** | | | | | | | | | |
| Norwegian Nitrate of Lime | 13* | .. | .. | .. | No* | 1.0 | .0 | .. | .. |
| **Carroll S. Page, Hyde Park, Vt.** | | | | | | | | | |
| Acid Phosphate | ... | .. | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| Muriate of Potash | ... | .. | .. | 48 | Yes | .. | .. | .. | C |
| Nitrate of Soda | 16 | .. | .. | .. | No | 1.0 | .0 | .0 | .. |
| No Filler Brand | 2.88 | 15 | 10 | .. | Yes | .6 | .4 | .6 | .. |
| No Filler Fertilizer Potash Brand | 3.29 | 11.5 | 9 | 4 | Yes | .7 | .3 | .6 | C |
| Raw Ground Bone | 3.7 | 22 | .. | .. | Yes | .0 | 1.0 | .0 | .. |
| Tankage | 5.75 | 15 | .. | .. | No | .3 | .7 | .0 | .. |
| **Parmenter & Polsey Fertilizer Co., 41 North Market St., Boston, Mass.** | | | | | | | | | |
| One-Ten-One for Grain and Grass | 0.82 | 11 | 10 | 1 | Yes | .6 | .4 | .9 | C |
| Plymouth Rock Brand 3/8/4 for All Crops | 2.46 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Three-Six-Ten for Corn, Potatoes and Vegetables | 2.46 | 7 | 6 | 10 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Three for Corn, Fruit and Vegetables | 1.64 | 9 | 8 | 3 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Two for Farm and Garden | 1.64 | 9 | 8 | 2 | Yes | .7 | .3 | .9 | C |
| Two-Eight-Six for Grain, Grass and Potatoes | 1.64 | 9 | 8 | 6 | Yes | .6 | .4 | .9 | C |

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CONDENSED STATEMENT AS TO GUARANTIES AND ANALYSES

| BRAND | Guaranties | | | | Guaranty met? | Nitrogen | | Proportion total phos. acid available | Potash, as muriate (C) or sulphate (S) |
|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Total phosphoric acid | Available phosphoric acid | Potash | | Water-soluble | Water-insoluble | | |
| **Pulverized Manure Co., 828 Exchange Ave., Union Stock Yards, Chicago, Ill.** | | | | | | | | | |
| Wizard Brand Sheep Manure | 2 | 1.25 | .. | 2 | Yes | * | * | * | * |
| **Reading Bone Fertilizer Company, Reading, Pa.** | | | | | | | | | |
| Acid Phosphate (16%) | ... | 17 | 16 | .. | Yes | .0 | .0 | 1.0 | .. |
| Blood, Meat and Potash Mixture | 1.64 | 9 | 8 | 4 | Yes | .8 | .2 | .9 | C |
| Economy Brand | ... | 11 | 10 | 4 | Yes | .0 | .0 | 1.0 | C |
| Farmers' Tankage and Potash | 0.82 | 11 | 10 | 2 | Yes | .7 | .3 | .9 | C |
| Reading All Crop Special | 1.64 | 11 | 10 | 6 | Yes | .8 | .2 | .9 | C |
| Reading One-Eight-Five | 0.82 | 9 | 8 | 5 | Yes | .7 | .3 | .9 | C |
| **Rogers & Hubbard Company, Middletown, Conn.** | | | | | | | | | |
| Acid Phosphate | ... | .. | 16 | .. | Yes | .. | .. | 1.0 | .. |
| "Bone Base" Fertilizer for Seeding Down | 2.46 | 15 | 6 | 4 | Yes | .7 | .3 | .8 | SC |
| "Bone Base" Oats and Top Dressing | 8.22 | 8 | 3 | 8 | Yes | 1.0 | .0 | .5 | C |
| "Bone Base" Soluble Corn and General Crops Manure | 2.46 | 10 | 8 | 6 | Yes | .8 | .2 | .8 | C |
| "Bone Base" Soluble Potato Manure | 5 | 10 | 8 | 5 | No | .8 | .2 | .8 | CS |
| Complete Phosphate | 0.82 | 11 | 10 | 3 | Yes | .5 | .5 | .9 | C |
| Four-Eight-Four | 3.29 | 9 | 8 | 4 | Yes | .8 | .2 | .8 | C |
| One-Eight-Two | 0.82† | 9 | 8 | 2 | Yes | .4 | .6 | .8 | C |
| Potato Phosphate | 1.64 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| Pure Fine Bone | 3.29 | 20.59 | .. | .. | Yes | * | * | * | .. |
| Three-Eight-Ten | 2.47 | .. | 8 | 10 | Yes | .8 | .2 | .8 | C |
| **F. S. Royster Guano Company, Baltimore, Md.** | | | | | | | | | |
| Acid Phosphate (16%) | ... | .. | 16 | .. | Yes | .. | .. | .9 | .. |
| Fine Ground Bone Meal | 2.47 | 22.9 | .. | .. | Yes | .. | .. | .. | .. |
| Landmark Brand | 3.29 | 10.5 | 10 | .. | Yes | .7 | .3 | .9 | .. |
| Muriate of Potash | ... | .. | .. | 49 | Yes | .. | .. | .. | C |
| Nitrate of Soda | 15 | .. | .. | .. | Yes | 1.0 | .0 | .. | .. |
| Tankage | 5.76 | 6.97 | .. | .. | Yes | .2 | .2 | .. | .. |
| Truckers' Delight | 3.29 | 9 | 8 | 4 | Yes | .7 | .3 | .8 | C |
| **Sanderson Fertilizer & Chemical Company, New Haven, Conn.** | | | | | | | | | |
| Corn Superphosphate | 1.65 | 9 | 8 | 2 | Yes | .5 | .5 | .9 | C |
| Potato Manure | 2.46 | 9 | 8 | 4 | Yes | .7 | .3 | .9 | C |
| **Virginia-Carolina Chemical Company, Room 2249, 120 Broadway, New York, N. Y.** | | | | | | | | | |
| Eureka Brand | 1.64 | 9 | 8 | 10 | Yes | .8 | .2 | .9 | C |
| Perfection Brand | 2.47 | 10 | 9 | 5 | Yes | .8 | .2 | .9 | C |
| Phospho Tobacco | ... | .. | 13 | .. | Yes | .. | .. | 1.0 | .. |
| Star Brand | ... | .. | 20 | .. | Yes | .. | .. | 1.0 | .. |
| Universal Brand | ... | .. | 16 | .. | Yes | .. | .. | 1.0 | .. |

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*Not determined.
†Quality of organic nitrogen: Not passed.

The revised fertilizer law requires that purveyors of lime "shall state (upon the packages as a guaranty) minimum and maximum percentages of (a) total lime, (b) total magnesia, (c) lime and magnesia combined as carbonates." They do not seem in all cases to have followed the letter of the law, but have furnished as a rule the essential information needed to enable the buyer to determine what he is purchasing. The analytical results follow:

**1. Amsden Lime Company's Agricultural Lime.**
**3.* Champlain Valley Lime Company's Lime and Ashes.**
**4. Champlain Valley Lime Company's Ground Limestone.**
**6. Pownal Lime Company's Ground Limestone.**
**7. Producers' Sales Company's Oyster Shell Lime.**
**10. Vermarco Lime Company's Agricultural Lime.**
**11. Vermarco Lime Company's Ground Limestone.**

| | Lime (CaO) found | Lime (CaO) guaranteed | Calcium carbonate ($CaCO_3$) found | Calcium carbonate ($CaCO_3$) guaranteed | Magnesia (MgO) found | Magnesia (MgO) guaranteed | Magnesium carbonate ($MgCO_3$) found | Magnesium carbonate ($MgCO_3$) guaranteed | Total carbonates ($CaCO_3$ + $MgCO_3$) found | Total carbonates ($CaCO_3$ + $MgCO_3$) guaranteed | Insoluble matter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | .... | .. | 55.56 | 64 | .... | .. | 44.21 | 31 | .... | .. | 1.73 |
| 3.* | 53.60 | 48 | .... | .... | 2.83 | 1 | .... | .... | .... | .. | 5.09 |
| 4. | 52.24 | 50 | .... | .... | 2.45 | 1.5 | .... | .... | 98.43 | 93 | 1.61 |
| 6. | .... | .. | 80.06 | 80 | .... | .. | 14.40 | 11 | 94.46 | 91 | 5.04 |
| 7. | .... | .. | 86.95 | 88.53 | .... | .. | 1.63 | 2.22 | .... | .. | 6.85 |
| 10. | 70.36 | 68 | .... | .... | 1.92 | 3 | .... | .... | .... | .. | 1.85 |
| 11. | .... | .. | 94.16 | 96 | .... | .. | 2.11 | 1 | .... | .. | 2.96 |

*No. 3 (Lime and ashes) contains also 1.02% potash (0.5% guaranteed) and 0.16% total phosphoric acid (0.4% guaranteed).

These goods, with a single exception, are as represented. The Amsden lime, however, does not maintain its guaranty. It contains more than the promised amount of total carbonates but in different proportions. It is a dolomitic limestone, represented by its guaranty to carry approximately $\frac{2}{3}$ calcium carbonate and $\frac{1}{3}$ magnesium carbonate, whereas, as a matter of fact, the sample drawn at their works carried respectively $\frac{4}{7}$ and $\frac{3}{7}$.

It will be noted that sometimes the guaranty given for an agricultural lime is stated as carbonate, despite the fact that there should be little carbonate present. In such cases the analytical result is calculated on the basis of the guaranty.

## DISCUSSION OF THE RESULTS OF INSPECTION

The following cases seem to call for special notice:

### AMERICAN AGRICULTURAL CHEMICAL COMPANY

*Patapsco Matchless Potash Manure.* Available phosphoric acid 0.4% short of guaranty, but potash 0.8% above guaranty. No shortage in total plant food.

### ARMOUR FERTILIZER WORKS

*Three-Eight-Four.* Potash 0.2% short of guaranty. Nitrogen and available phosphoric acid just meet guaranties. Shortage in total plant food 3%.

### BOWKER FERTILIZER COMPANY

*Hill and Drill Phosphate.* Nitrogen 0.4% short of guaranty, but potash 1.1% over guaranty. No shortage in total plant food.

### JOS. BRECK & SONS CORPORATION

*Ram's Head Sheep Manure.* A single lot of one ton was found on sale. The bags were uniformly guarantied as to their potash contents (3%), but variously guarantied as to their contents of nitrogen (2.16, 1.84, 1.46%) and phosphoric acid (1.25 total 0.75% available). This situation was not observed by the sampling agent, but was determined on resurvey after the jobber protested the advance report of analysis and guaranty.

The practice of multiple guaranty is not illegal, provided each bag actually contains the plant food actually guaranteed by its label. However, such a practice does not tend to inspire confidence on the part of buyers. In this instance the sampling agent drew samples from at least five bags. It is quite impossible to state how many 1.46's, 1.84's or 2.16's he used, nor how many of each grade were originally carried in this shipment. All that can be said is that the sample drawn contained the guarantied amounts of phosphoric acid and potash and 1.61% of nitrogen, thus approximating the lower nitrogen guaranty statement.

### CONSOLIDATED RENDERING COMPANY

*Nitrate of Soda.* Nitrogen 0.5% short of guaranty. Shortage in total plant food 3%.

*Tankage.* Nitrogen 0.3% short of guaranty, but total phosphoric acid 4.4% above guaranty. No shortage in total plant food.

### EARP-THOMAS CULTURES CORPORATION

*Stim-U-Plant.* Nitrogen 0.6% and available phosphoric acid 0.6% short of guaranty. Shortage in total plant food 3%.

### LOWELL FERTILIZER COMPANY

*Four-Eight-Four.* Nitrogen 0.1% and available phosphoric acid 0.2% short of guaranty, but potash 0.4% above guaranty. No shortage in total plant food.

### NEW ENGLAND FERTILIZER COMPANY

*Two-Eight-Six.* Available phosphoric acid 0.6% short of guaranty, but nitrogen and potash 1.1% above guaranty. No shortage in total plant food.

*Five-Eight-Seven.* Nitrogen 0.2% and available phosphoric acid 0.5% short of guaranty, but potash 0.5% above guaranty. Shortage in total plant food 1%.

*Four-Eight-Four.* Nitrogen 0.5% and available phosphoric acid 0.4% short of guaranty, but potash 0.2% above guaranty. Shortage in total plant food 4%.

### NORWEGIAN-NITRATE PRODUCTS COMPANY

*Nitrate of Lime.* Nitrogen 1.4% or 0.4% short of guaranty, according to which is taken as the legal guaranty. Shortage in total plant food 11% or 3%, as the case may be.[1]

### CARROLL S. PAGE

*Nitrate of Soda.* Nitrogen 0.7% short of guaranty. Shortage in total plant food 4%.

*Tankage.* Nitrogen 1.1% short of guaranty, but total phosphoric acid 3.7% above guaranty. No shortage in total plant food.

*No-Filler-Potash Brand.* Potash 0.3% of guaranty, but nitrogen 1% above guaranty. No shortage in total plant food.

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[1] This company made a guaranty of 13 percent nitrogen and the license was issued on that basis and the goods so branded. Under date of May 4, after sales had been consummated and samples drawn, it stated its desire "to change the nitrogen guaranty to 12 percent" on the ground that the product might have absorbed water. It pointed out that such absorption, if it took place, would tend to increase the package weight and in no respect to lower the actual amount of nitrogen present in terms of weight. Under date of May 8 the company was advised that the guaranty was "the statement which met the eye of the purchaser affixed to the package" and that the writer had no power to permit modification after sales had been made. It was further advised to notify each Vermont purchaser, giving the reasons why it desired to change the guaranty, setting forth that the change in nowise diminished the total amount of nitrogen purchased.

It will be observed that the goods fail to meet guaranty on either the 13 or the 12 percent basis. A material of this character is difficult to handle in fertilizer inspection.

### ROGERS & HUBBARD COMPANY

*Soluble Potato Manure.* Nitrogen 0.5% short of guaranty, but available phosphoric acid 0.6% and potash 0.7% above guaranty. No shortage in total plant food.

*Three-Eight-Ten.* Available phosphoric acid 0.4% short of guaranty, but nitrogen 0.4% and potash 0.9% above guaranty. No shortage in plant food.

### ROYSTER GUANO COMPANY

*Landmark Guano.* Nitrogen 0.3% short of guaranty, but available phosphoric acid 1.3% above guaranty. No shortage in total plant food.

*Quantity of plant food.* The fertilizers sold in Vermont during the spring of 1922—if one may judge by the results of inspection—as a whole were up to the usual grade. There were 506 guaranties made, 31 of which, or 1 in 16, were not maintained. Twelve of these represented shortages of 0.25% or less, while only 10 were in excess of 0.50%. The distribution of these 10 shortages is interesting: Mixed fertilizers 2, nitrates 3, sheep manures 2, special preparation for flowers 2, tankage 1. In the 18 cases cited on pages 12-13 "no shortage in total plant food" is indicated 10 times, the deficiency in one or more plant foods being compensated for by excess over guaranty of other forms. In the other instances, the shortages in 6 cases ranged from 1 to 4%. The other two cases represented a deliquescent nitrate of lime[1] and an over-guaranteed sheep manure. The manufacturers as usual and very properly furnished little more plant food than they promised to supply. The average mixed fertilizer was guaranteed to carry approximately 2⅓% nitrogen, 9% total and 8% available phosphoric acid and 4¼% potash. It averaged to contain not more than 5% in excess of these figures, that is to say, for every 100% of total plant food guaranteed, on the average not more than 105% was furnished.

*Quality of plant food.* The information formerly furnished as to the nitrate and ammoniacal nitrogen contents of the several brands of mixed fertilizers can not be furnished at present owing to the insufficiency of the funds available for control work. However, the availability of the organic nitrogen was determined as usual. Only one brand was found to contain what seemed to be an undue amount of unavailable organic nitrogen, namely, Rogers & Hubbard's One-Eight-Two. This is the best result secured at this Station during its 20 years of study of the character of the organic nitrogen in fertilizers.

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[1] See footnote statement on page 18.

The proportion of the total phosphoric acid furnished in an available form is greater today than in former years. Twelve percent of the brands carrying available phosphoric acid contained over 95% of the total phosphoric acid in available form; 70% contained from 85 to 95% in available form; 15% from 75 to 85% in available form; and only four brands contained less than 75% in available form—an admirable showing.

The average potash content of the goods is quite up to that of the pre-war basis.

A survey of the reported selling prices indicates that the prices indicated below for the grades specified approximately represent the average figures. These grades doubtless cover more than 4/5, perhaps more than 9/10, of the total Vermont sales of mixed fertilizers. However, great variations occurred. For example, 13 selling prices for a certain grade of goods ranged from $35 to $44; 11 of another grade from $39 to $47, and the extremes were observed at not distant points. Furthermore, no greater fluctuations occurred than usual, a lessened tendency towards price standardization being found than in the past. Hence the figures do not mean much.

| | | | | | |
|---|---|---|---|---|---|
| 12–2, | $36. | 1–8–1, | $34. | 1–8–2, | $36. |
| 2–8–2, | $39. | 2–8–3, | $42. | 2–8–6, | $46. |
| 3–9–2, | $42. | 3–8–4, | $46. | 3–6–10, | $50. |
| 4–8–4, | $49. | 4–8–7, | $49. | 4–6–10, | $53. |
| 5–8–7, | $49. | 6–6–4, | $54. | | |

## FEEDING STUFFS INSPECTION

The sampling agents of the Station visited 58 cities, towns and villages in Vermont in the winter and spring of 1922, and drew 762 samples from dealers' stocks, representing 294 brands of goods which are subject to guaranty. The samples have been examined chemically for protein only because of lack of funds.

The law seems fairly well observed at present. Unguaranteed goods are infrequent and overguaranties are not as common as once they were; but overstatements in advertising still occur.

The following condensed statements set forth the facts as to protein guaranty maintenance as determined in the present inspection. Within groups, the order of statement is alphabetical by names of manufacturers or jobbers. Manufacturers' or jobbers' names and addresses are printed in SMALL CAPITALS, brand names in *italics*, guaranties in figures in parenthesis following the brand name. The deficiency in protein contents, if any, is stated following the guaranty in *italics*.

## COTTONSEED MEALS

### PROTEIN GUARANTIES FULFILLED

American Cotton Oil Co., New York, N. Y., *Aco* (41.18); *Surety* (36). Ashcroft-Wilkinson Co., Atlanta, Ga., *Helmet* (41); *Monarch* (43); *Paramount* (36). F. W. Brodé Co., Memphis, Tenn., *Owl* (43). Cameron-Daniel Co., Atlanta, Ga., *Good* (36). S. P. Davis, Little Rock, Ark., *Good Luck* (41); *Beauty* (36). Forest City Cotton Oil Co., Forest City, Ark., *Pointer* (43). Humphreys-Godwin Co., Memphis, Tenn., *Danish* (36), (36); *Dixie* (41). Jennings, Brown Co., ————, *Palomer* (41). L. B. Lovett & Co., Memphis, Tenn., *36 Brand* (36). Lyle & Lyle, Huntsville, Ala., *Economy* (36), (36). Marianna Cotton Oil Co., Marianna, Ark., *White Mule Brands: Good* (36); *Prime* (41), (43), (43). East St. Louis Cotton Oil Co., East St. Louis, Ill., *St. Clair* (36). A. C. Westervelt & Co., Memphis, Tenn., *Planet* (43).

### PROTEIN GUARANTIES NOT FULFILLED

American Cotton Oil Co., New York, N. Y., *Longhorn Prime* (guaranty 43, analysis 41.4). Ashcroft-Wilkinson Co., Atlanta, Ga., *Monarch* (guaranty 43, analysis 41.9); *Paramount* (guaranty 36, analysis 33.8). F. W. Brodé Co., Memphis, Tenn., *Owl* (guaranty 36, analysis 34.9). S. P. Davis, Little Rock, Ark., *Good Luck* (guaranty 41, analysis 38.4). Humphreys-Godwin Co., Little Rock, Ark., *Bull* (guaranty 43, analysis 41), (guaranty 43, analysis 41.4); *Dixie* (guaranty 41, analysis 37.9).

## LINSEED MEAL

### PROTEIN GUARANTIES FULFILLED

American Linseed Co., Buffalo, N. Y., *Old Process Oil Meal* (36), (35), (35), (35), (34), (34). American Milling Co., Peoria, Ill., *Amco Old Process and Screenings* (30). Archer-Daniels Linseed Co., Buffalo, N. Y., *Old Process Ground Oil Cake* (34), (34). Kelloggs & Miller, Amsterdam, N. Y., *Old Process* (30), (31). Midland Linseed Products Co., Minneapolis, Minn., *Pure Old Process Ground Linseed Cake* (34); *Argentine Old Process* (33). Toledo Seed & Oil Co., Toledo, Ohio, *Old Process* (33).

### PROTEIN GUARANTIES NOT FULFILLED

Spencer Kellogg & Sons, Inc., Undercliff, N. J., Buffalo, N. Y., *Pure Old Process Oil Meal* (guaranty 31, analysis 29.5).

## GLUTEN MEAL AND FEEDS

### PROTEIN GUARANTIES FULFILLED

American Maize Products Co., New York, N. Y., *Cream of Corn* (23), (23). Clinton Corn Syrup Refining Company, Clinton, Iowa, *Clinton* (23), (23). Corn Products Refining Co., New York, N. Y., *Diamond* (Meal) (40), (40); *Buffalo* (23), (23). J. C. Hubinger Bros. Co., Keokuk, Iowa, *KKK* (23). A. E. Staley Manufacturing Co., Decatur, Ill., *Staley's* (23), (23).

## DISTILLERS' AND BREWERS' BY-PRODUCTS

### PROTEIN GUARANTIES FULFILLED

Donahue-Stratton Co., Milwaukee, Wis., *Calgary Distillers' Grains* (26). Farmers' Feed Co., New York, N. Y. *Bull Brand Brewers' Grains* (21). Fleischmann Co., Peekskill, N. Y., *Fleischmann's Dried Grains* (17), (17). Rossville Co., Lawrenceville, Ind., *Rossville Distillers' Grains* (30).

### PROTEIN GUARANTIES NOT FULFILLED

Farmers' Feed Co., New York, N. Y., *Bull Brand Brewers' Grains* (guaranty 21, analysis 19.1).

## WHEAT OFFALS—WHEAT BRAN

### PROTEIN GUARANTIES FULFILLED

Anthony Mills, Anthony, Kan., *Wheat Bran and Wheat Screenings (not to exceed 8%)* (14.5). E. W. Bailey & Co., Montpelier, Vt., *Pennant* (14.5). Commander Milling Co., Minneapolis, Minn., *Commander* (14.5),* (11.5). Duluth-Superior Milling Co., Duluth, Minn., *Duluth Imperial** (15.5). Duluth Universal Milling Co., Duluth, Minn., *Duluth** (13.8), (13.8). Everett, Aughenbaugh Co., Waseca, Minn., *Pure* (14.6). Federal Mill & Elevator Co., Inc., Lockport, N. Y., *Lucky** (12), (15); *Dairy Maid* (12.5). International Milling Co., Indianapolis, Ind., *Blackhawk* (14.5), (14.5). Lamar Flour Mills Co., Lamar, Col., ———— (14.5). Larabee Flour Mills Corporation, Kansas City, Mo., ————,* (15). Maney Milling Co., Omaha Milling Co., Omaha, Neb., ————,* (14). Midland Flour Milling Co., Kansas City, Mo., ———— (14.5). National Feed Co., St. Louis, Mo., *National* (14.5), (14.5). Northwestern Consolidated Milling Co., Minneapolis, Minn., ———— (13). Ogdensburg Roller Mills, Ogdensburg, N. Y., *Ogdensburg** (15). Pillsbury Flour Mills Co., Minneapolis, Minn., *Pillsbury's** (13), (13), (14). Quaker City Flour Milling Co., Philadelphia, Pa., ———— (13). Red Star Milling Co., Wichita, Kans.* (15). Southwestern Milling Co., Inc., Kansas City, Mo., *Red Turkey* (14.5). Stokes Milling Co., Watertown, So. Dak., *Garland** (16.1). David Stott Flour Mills, Inc., Detroit, Mich., ————* (14.5). Superior Milling Co., Superior, Wis., *Duluth Imperial* (15.5). Valley City Milling Co., Grand Rapids, Mich., *Rowena* (14). Voight Milling Co., Grand Rapids, Mich., *Voight's* (14.5). Washburn-Crosby Co., Minneapolis, Minn., ————* (13), (14); *Durum* (12). Western Canada Flour Mills Co., Ltd., Winnipeg, Man., *Pioneer* (14.5). Weber Flour Mills Corp., Salina, Kans., *Tea Table* (14.5); ————* (14.5). Yerxa, Andrews & Thurston, Minneapolis, Minn., *Durum* (14).

## WHEAT OFFALS—WHEAT MIDDLINGS

### PROTEIN GUARANTIES FULFILLED

Bill, Bell & Co., Ogdensburg, N. Y., *Flour** (16.18); *Shorts** (16). Commander Milling Co., Minneapolis, Minn., *Commander** (16). Consolidated Milling Co., Minneapolis, Minn., *Standard* (14). Crookston Milling Co., Crookston, Minn., *Fine** (15.3). Eagle Roller Mills Co., New Ulm, Minn., ————* (15). Federal Mill & Elevator Co., Inc., Lockport, N. Y., *Dairy Maid** (13); *Luck* (16.5). International Milling Co., Minneapolis, Minn., *Black Hawk Standard** (15). Maple Leaf Milling Co., Ltd., Toronto, Ont., *Rex** (16). Mosley & Motley Milling Co., Rochester, N. Y., *Mosley & Motley** (15), (15). Newsome Feed & Grain Co., Pittsburg, Pa., *Palmo* (16). Niagara Falls Milling Co., Niagara Falls, N. Y., *Niagara* (16.5). Northwestern Consolidated Milling Co., Minneapolis, Minn., *Standard** (14), (14); *Flour** (15). Ogdensburg Roller Mills, Ogdensburg, N. Y., *Gerna* (16). Pillsbury Flour Mills Co., Minneapolis, Minn., *Pillsbury's A** (15); *Standard B** (14); ———— (14); *Daisy XX* (16); *Daisy* (13). Russell-Miller Milling Co., Minneapolis, Minn., *Alta* (15), (15.3). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (14), (14). David Stott Flour Mills, Inc., Detroit, Mich., *Pennant* (15.5), (15.5); *Rye* (10). Tennant & Hoyt, Lake City, Minn., *Tennant & Hoyt** (16). Thornton & Chester Milling Co., Buffalo, N. Y., *Thornton & Chester** (15). Thompson Milling Co., Lockport, N. Y., *Angelus** (11). Valley City Milling Co. Grand

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*With ground screenings not exceeding mill run.

Rapids, Mich., *Farmers' Favorite** (13). Washburn-Crosby Milling Co., Minneapolis, Minn., *Standard** (14), (14), (15); *Adrain Red Dog* (16.2).

## WHEAT OFFALS—WHEAT MIXED FEED

### PROTEIN GUARANTIES FULFILLED

Ansted & Burke Co., Springfield, Ohio, *William Tell* (15.5). E. W. Bailey & Co., Montpelier, Vt., *Fancy* (15); *Capital* (14), (14). Caledonia Mills, Inc., St. Johnsbury, Vt., *Brooks' Fancy* (16). Federal Mill & Elevator Co., Inc., Lockport, N. Y., *Dairy Maid** (13), (14); *Lucky* (12). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal Fancy** (15). National Milling Co., Toledo, Ohio, *Osota** (15), (15); *Pennant* (15), (15). Northwestern Consolidated Milling Co., Minneapolis, Minn., *Planet* (15), (15). Pillsbury Flour Mills Co., Minneapolis, Minn., *Daisy* (16), (16); *Fancy** (14), (14). Portland Milling Co., Portland, Mich., *Champion** (13.96). Postum Cereal Co., Battle Creek, Mich., *Burt's Cereal* (17). Russell-Miller Milling Co., Minneapolis, Minn., *Occident** (15). St. Albans Grain Co., St. Albans, Vt., *Wirthmore** (15), (15); *Welden**† (12), (12). C. A. Smith, St. Johnsbury, Vt., *Smith's Fancy** (15). F. W. Stock & Sons, Hillsdale, Mich., *Monarch** (16); *Superior** (16). David Stott Flour Mills, Inc., Detroit, Mich, *Stott's Honest* (14.5), (14.5). Thompson Milling Co., Lockport, N. Y., ———* (15.57). Valley City Milling Co., Grand Rapids, Mich., *Rowena** (15). Boutwell Milling & Grain Co., Troy, N. Y., *Boutwell Rye** (13.5).

## WHEAT OFFALS—RED DOG FLOUR

### PROTEIN GUARANTIES FULFILLED

Duluth-Superior Milling Co., Superior, Wis., ——— (16). Empire Milling Co., Minneapolis, Minn., *Ivanhoe* (18), (18). Larabee Flour Mills Corp., Kansas City, Mo., ——— (15). Marshall Milling Co., Marshall, Minn., ——— (15.7). Niagara Falls Milling Co., Niagara Falls, N. Y., ——— (14). Northwestern Consolidated Milling Co., Minneapolis, Minn., *XXX Comet* (16). Red Wing Milling Co., Red Wing, Minn., *Bixota* (14.5). George Urban Milling Co., Buffalo, N. Y., ——— (16). Washburn-Crosby Co., Minneapolis, Minn., *Arlington* (14); *Adrian* (16), (16).

## OAT HULLS, ETC.

### PROTEIN GUARANTIES FULFILLED

Armour Grain Co., Chicago, Ill., ——— (4), (4). Northern Illinois Cereal Co., Lockport, Ill., *Reground Oat Feed* (3.5).

## HOMINY FEEDS

### PROTEIN GUARANTIES FULFILLED

Acme-Evans Co., Indianapolis, Ind., *Homilk* (8.5). American Hominy Co., Indianapolis, Ind., *Homco* (10). Evans Milling Co., Indianapolis, Ind., *Emco Evans* (10). Farmers' Cooperative Elevator Co., Seymour, Ind., *Farmers'* (10). Kellogg Toasted Corn Flakes Co., Battle Creek, Mich., *White* (10). Landish Milling Co., Milwaukee, Wis., *True Value* (10.5). Mystic Mills Milling Co., Sioux City, Iowa, *Mystic Yellow* (8.5). Plymouth Milling Co., Le Mars, Iowa, *Plymouth* (10), (10). Quaker Oats Co., Chicago, Ill., *Yellow* (10.5), (10.5). Snyder Milling Co., Chillicothe, Ohio, *Logan* (10).

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*With ground screenings not exceeding mill run.

†Contains white corn flour.

## ALFALFA MEAL

### PROTEIN GUARANTIES FULFILLED

Denver Alfalfa Milling & Products Co., Lamar, Colo., ————, (12), (12). Otto Weiss Milling Co., Wichita, Kans., *Otto Weiss* (12).

## DRIED BEET PULP

### PROTEIN GUARANTIES FULFILLED

Clover Leaf Milling Co., Buffalo, N. Y., *Clover Leaf* (8). Great Western Sugar Co., Denver, Colo., ————, (8). Larrowe Milling Co., Detroit, Mich., ———— (8), (8). Michigan Sugar Co., Saginaw, Mich., ———— (8).

## PROPRIETARY FEEDS—DAIRY

### PROTEIN GUARANTIES FULFILLED

Addison County Farmers' Exchange, Middlebury, Vt., ———— (20). Arcady Farms Milling Co., Chicago, Ill., *Riverdale* (24). Armour Grain Co., Chicago, Ill., *Armour's* (22). E. W. Bailey & Co., Montpelier, Vt., *Capital* (23), (23). Caledonia County Farm Bureau Exchange, Inc., St. Johnsbury, Vt., *Farmers' Ideal Dairy Ration* (22). Caledonia Mills, St. Johnsbury, Vt., *Eastern States* (22). Chapin & Co., Hammond, Ind., *Unicorn* (24), (24), (24). City Feed Co., St. Albans, Vt., *Farmers' Favorite* (25), (25). Clover Leaf Milling Co., Buffalo, N. Y., *Advanced Registry* (25); *Peerless* (20); *Clover Leaf* (16). E. Crosby & Co., Brattleboro, Vt., *Ready Ration* (25). Elmore Milling Co., Oneonta, N. Y., *Elmore Milk Grains* (25); *Dairy Ration* (25). J. E. Foster, South Royalton, Vt., *Farm Bureau Formula* (20). D. H. Grandin Milling Co., Jamestown, N. Y., *Twin Six* (22). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (24); *Krackerjack* (20). International Sugar Feed Co., Minneapolis, Minn., *Diamond* (24); *Minnesota Dairy* (10.6). Kasco Mills, Inc., Toledo, O., *Beats All Milk Grains* (22), (22). F. D. Lapelle, Swanton, Vt., *23% Dairy Ration* (23). Larrowe Milling Co., Detroit, Mich., *Larro Feed* (20), (20); *Big Six Complete* (21). Park & Pollard Co., Boston, Mass., *Stevens 44* (24), (24). C. C. Patterson & Co., Memphis, Tenn., *Quarto* (24). Pillsbury Flour Mills Co., Minneapolis, Minn., *Pillsbury's* (20). Quaker Oats Co., Chicago, Ill., *Big Q* (21). Ralston Purina Co., Inc., St. Louis, Mo., Buffalo, N. Y., *Purina Cow Chow Feed* (24). St. Albans Grain Co., St. Albans, Vt., *Paragon* (22), (22); *Wirthmore Balanced Ration* (25), (25), (24); *Wirthmore Dairy Feed with Beet Pulp* (21), (21). Ubiko Milling Co., Cincinnati, O., *Union Grains* (24), (24). United States Food Products Corporation, Peoria, Ill., *Farmer Jones* (20); *Melocorn* (20). Westerly Grain & Flour Co., Westerly, R. I., *Favorite* (18).

### PROTEIN GUARANTIES NOT FULFILLED

Caledonia Mills, St. Johnsbury, Vt., *Green Mountain* (guaranty 23, analysis 21.9). E. Crosby & Co., Brattleboro, Vt., *Ready Ration* (guaranty 25, analysis 24.2). W. B. Johnson & Co., Essex Junction, Vt., *Johnson's Perfection Dairy No. 1* (guaranty 22, analysis 20.8). Maritime Trading Corporation, Buffalo, N. Y., *Bull Brand* (guaranty 24, analysis 22.2; guaranty 24, analysis 23). St. Albans Grain Co., St. Albans, Vt., *Wirthmore Balanced Ration* (guaranty 26, analysis 24.7). C. A. Smith, St. Johnsbury, Vt., *Smith's* (guaranty 23, analysis 21.7).

## PROPRIETARY FEEDS—STOCK

### PROTEIN GUARANTIES FULFILLED

E. W. Bailey & Co., Montpelier, Vt., *Pennant* (9), (9). Clover Leaf Milling Co., Buffalo, N. Y., *Black Beauty Horse* (10). E. Crosby & Co., Brattleboro, Vt., *Zenith* (8.5). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's* (9). F. D. Lapelle, Swanton, Vt., ————, (9). Purity Oats Co., Davenport, Iowa, *Iowa* (10), (10). Quaker Oats Co., Chicago, Ill., *Schumacher* (10), (10); *Sugared Schumacher* (10), (10); *Vim* (5), (5); *White Diamond* (8), (8.5). Ralston Purina Co., St. Louis, Mo., *Purina O-Molene* (9.7). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (9), (9); *Charlestock* (10). David Stott Flour Mills Co., Inc., Detroit, Mich., *Stott's Winner Chop* (8.5). Stratton & Co., Concord, N. H., *Stratton 24* (7.5). United States Food Products Corporation, Peoria, Ill., *Tes-Ted* (10), (10).

## PROPRIETARY FEEDS—CALF

### PROTEIN GUARANTIES FULFILLED

Blatchford's Calf Meal Co., Waukegan, Ill., *Blatchford's* (24), (24). Quaker Oats Co., Chicago, Ill., *Schumacher* (18). Ryde & Co., Chicago, Ill., *Ryde's Cream Quality* (25).

### PROTEIN GUARANTIES NOT FULFILLED

Ralston Purina Co., St. Louis, Mo., *Purina Calf Chow* (guaranty 27, analysis 25). Ryde & Co., Chicago, Ill., *Ryde's Cream Quality* (guaranty 25, analysis 23.7).

## PROPRIETARY FEEDS—SWINE

### PROTEIN GUARANTIES FULFILLED

Chapin & Co., Hammond, Ind., *Bicorn* (17.5). Park & Pollard Co., Boston, Mass., *Go-Tu-It* (15), (15). St. Albans Grain Co., St. Albans, Vt., *Wirthmore Hog* (17), (17); *Wirthmore Pig* (18), (18).

## PROPRIETARY FEEDS—POULTRY FEEDS—MASHES

### PROTEIN GUARANTIES FULFILLED

Caledonia Mills, St. Johnsbury, Vt., *Green Mountain* (19). Clover Leaf Milling Co., Buffalo, N. Y., *Clover Leaf Egg* (18). Cutler Co., Wilbraham, Mass., *King* (18). Elmore Milling Co., Oneonta, N. Y., *Elmore Egg* (18); *Growing Mash* (17). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's Dry (with Buttermilk)* (20). Hales & Hunter Co., Chicago, Ill., *Red Comb Egg* (16). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (20). W. B. Johnson & Co., Essex Junction, Vt., *Johnson's* (16). Kasco Milling Co., Toledo, O., *Fullnest* (20), (18.5). F. D. Lapelle, Swanton, Vt., *Egg Producing* (18). Park & Pollard Co., Boston, Mass., *Lay or Bust* (18), (18). Purity Oats Co., Davenport, Iowa, *Iowa* (18). Quaker Oats Co., Chicago, Ill., *Full-O-Pep* (20), (20). St. Albans Grain Co., St. Albans, Vt., *Wirthmore Buttermilk* (20). W. R. White, North Bennington, Vt., *Flynn's* (18).

## PROPRIETARY FEEDS—POULTRY FEEDS—SCRATCH FEEDS

### PROTEIN GUARANTIES FULFILLED

Armour Grain Co., Chicago, Ill., *Iroquois* (10). Black Rock Milling Co., Black Rock, N. Y., *Pontiac* (10). Elmore Milling Co., Oneonta, N. Y., *Elmore* (10). D. H. Grandin Milling Co., Jamestown, N. Y., *Grandin's* (10). Hale & Hunter Co., Chicago, Ill., *Red Comb* (10). E. T. & H. K. Ide, St. Johnsbury, Vt., *Ideal* (10). Kasco Mills, Waverly, N. Y., *Kasco* (10). Maritime Trading Corporation, Buffalo, N. Y., *Bull Brand* (11). Park & Pollard Co., Boston, Mass., *Red Ribbon* (10), (10); *Pontiac* (10). Quaker Oats Co., Chicago, Ill., *Schumacher* (10); *Full-O-Pep* (10), (10). St. Albans Grain Co., St. Albans, Vt., *Wirthmore* (11), (11).

###### PROTEIN GUARANTIES NOT FULFILLED

QUAKER OATS CO., CHICAGO, ILL., *Early Bird* (guaranty 10, analysis 9.2).

## PROPRIETARY FEEDS—POULTRY FEEDS—CHICK FEEDS

###### PROTEIN GUARANTIES FULFILLED

ELMORE MILLING CO., ONEONTA, N. Y., *Elmore* (10). D. H. GRANDIN MILLING CO., JAMESTOWN, N. Y., *Grandin's* (10). F. D. LAPELLE, SWANTON, VT., *Baby Chick* (10). PARK & POLLARD, BOSTON, MASS., *Buttermilk Booster* (12); *Red Ribbon* (10); *Baby Buster* (11), (11); *Intermediate* (10), (10); *Bonnie Booster* (12). QUAKER OATS CO., CHICAGO, ILL., *Full-O-Pep Coarse* (10); *Full-O-Pep Fine* (10); *Schumacher Little Chick* (9). ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Wirthmore Buttermilk Baby Chick* (13.5); *Wirthmore Gritless* (11).

###### PROTEIN GUARANTIES NOT FULFILLED

ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Wirthmore Intermediate* (guaranty 11, analysis 10.1).

## PROPRIETARY FEEDS—POULTRY FEEDS—GROWING FEEDS

###### PROTEIN GUARANTIES FULFILLED

JOHN ESHELMAN & SONS, LANCASTER, PA., *Eshelman's Growing Mash* (16). D. H. GRANDIN MILLING CO., JAMESTOWN, N. Y., *Grandin's* (14). PARK & POLLARD CO., BOSTON, MASS., (10), (10), (10). QUAKER OATS CO., CHICAGO, ILL., *Full-O-Pep* (17), (17); *Full-O-Pep Fattening* (16). ST. ALBANS GRAIN CO., ST. ALBANS, VT., *Wirthmore* (15), (15).

## PROPRIETARY FEEDS—POULTRY FEEDS—MISCELLANY

###### PROTEIN GUARANTIES FULFILLED

BURLINGTON RENDERING CO., BURLINGTON, VT., *Burlington Poultry Food* (40). GREEN CHICK FEED CO., ————, *Green's Poultry Food* (35).

## DISCUSSION OF THE RESULTS OF INSPECTION

Samples were taken representing 63 brands of the high protein by-products (cottonseed and linseed meals, gluten feeds and meals, brewers' etc. dried grains), 24 brands of low protein products other than wheat offals (hominy feed, dried beet pulp, etc.), 123 brands of wheat offals (brans, middlings, mixed feeds, red dog flour) and 156 brands of proprietary brands (ready mixed rations for dairy cows, horses, poultry, calves, swine and stock in general).

Failure to guaranty is a thing of the past. In only two cases out of 762 was the guaranty missing. In one case the labels were so torn and obscure that no one could make them out; and the other represented a Farmers' Exchange selling from bulk stock and technically, not called upon to furnish a guaranty unless asked for it by the purchaser.

The general outcome is not materially unlike that observed in former years. Only 21 brands out of nearly 300 showed deficiencies that can be regarded as serious. The cottonseed meals were a bad lot. A third of the samples failed to meet their guaranties. Doubtless the desperate situation in the cotton belt led the mill men more freely than usual—and that is quite unnecessary—to grind the hulls into the meal. Eight lots (American Cotton Oil Co.'s *Longhorn Prime;* Ashcroft-Wilkinson Co.'s *Monarch* and *Paramount;* F. W. Brodé Co.'s *Owl;* S. P. Davis' *Good Luck;* Humphrey-Godwin's *Bull*—two samples—and *Dixie*) carried respectively only 96, 97, 94, 97, 94, 95, 96 and 88 percents of their guaranteed contents of crude protein. One linseed meal (Spencer-Kellogg & Sons' *Pure Old Process*) contained only 95% of its protein promise. A brewers' grains (Farmers' Feed Co.'s *Bull*) contained 91% of its promised protein. Seven lots of proprietary dairy feeds (Caledonia Mills' *Green Mountain;* Crosby's *Ready Ration;* Johnson's *Perfection No. 1;* Maratime Trading Corporation's *Bull*—two lots; St. Albans Grain Co.'s *Wirthmore Balanced Ration;* Smith's *Smith's*) were deficient so far as their guaranteed protein contents were concerned, carrying only 95, 97, 95, 93, 96, 95 and 94 percents thereof. Two calf meals (Ralston Purina Co.'s *Purina Calf Chow* and Ryde's *Cream Quality*) contained respectively 93 and 95 percents. Two poultry feeds (Quaker Oats' Co.'s *Early Bird;* St. Albans Grain Co.'s *Wirthmore Intermediate*) carried respectively 92 and 92 percents.

Less than 3 percent of the brands inspected were more than 5 percent deficient and only one in 294 more than 10 percent deficient.

## AGRICULTURAL SEED INSPECTION

The Station sampling agents visited fully 40 Vermont cities, towns and villages during April, 1922, and gathered 319 samples of agricultural seed offered for sale in the open markets by local dealers as follows:

| | |
|---|---|
| Alfalfa | 9 |
| Barley | 12 |
| Clover, alsike | 36 |
| Clover, red | 52 |
| Corn | 21 |
| Millet | 37 |
| Oats | 23 |
| Redtop | 21 |
| Timothy | 61 |
| Mixtures | 5 |
| Buckwheat | 6 |
| Clover, sweet and white | 5 |
| Orchard grass | 5 |
| Peas, field | 4 |
| Rape | 3 |
| Rye | 4 |
| Soya beans | 1 |
| Speltz | 1 |
| Sudan grass | 7 |
| Vetch | 1 |
| Wheat | 5 |

These samples were drawn in accordance with the official directions. Purity tests were made by the weight method and the germination tests were made according to the method employed by the Federal Department of Agriculture.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| | | ALFALFA | | |
| Grimm | Conklin | 99.85 | 83.5 | 360 |
| Grimm | Dickinson | 99.7 | 84 | 180 |
| ———— | Dickinson | 99 | 80.5 | 1350 |
| ———— | Dickinson | 99.74 | 88 | 90 |
| Honor | Stanford | 99.52 | 79.5 | 450 |
| Eureka | Whitney-Eckstein | 99.7 | 93 | 180 |
| Eureka | Whitney-Eckstein | 99.5 | 79.5 | 270 |
| Grimm | Whitney-Eckstein | 99* | 87 | 10170 |
| Northern | Whitney-Eckstein | 99.5 | 75 | 450 |
| | | BARLEY | | |
| Oderbrucker | Conklin | 98 | 98 | 30 |
| Oderbrucker | Conklin | 98 | 98.5 | 45 |
| 6-Row No. 115 | Dickinson | 97.29* | 99 | — |
| 6-Row | Dickinson | 96.42 | 98.5 | 45 |
| No. 1110 | Dickinson | 97.4 | 99.5 | — |
| 2-Row | Dickinson | 94.68 | 98 | 50 |
| White Mountain | Holbrook | 99* | 97.5 | — |
| 6-Row | Whitney-Eckstein | 98 | 97.5 | — |
| Oderbrucker | Whitney-Eckstein | 98 | 97.5 | — |
| 6-Row | Whitney-Eckstein | 98 | 83.5 | — |
| 6-Row | Whitney-Eckstein | 98 | 89.5 | — |
| 6-Row | Whitney-Eckstein | 98 | 86.5 | 45 |
| | | ALSIKE CLOVER | | |
| ———— | Barber-Bennett | 96 | 89.5 | 2925 |
| C. M. | Conklin | 95* | 90.5 | 5950 |
| C. M. | Conklin | 95 | 79.5 | 8100 |
| Imperial | Conklin | 97.55 | 87.2 | 1350 |
| Imperial | Conklin | 97.5 | 92 | 2925 |
| Ace 14 x 30 | Craver-Dickinson | 95 | 90 | 4050 |
| Pine Tree 14 x 32 | Craver-Dickinson | 96.4 | 90.5 | 4500 |
| Pine Tree | Craver-Dickinson | *96.9*† | 86 | 5175 |
| Ace | Dickinson | 95* | 85 | 6750 |
| Pine Tree 2164 | Dickinson | 97.15* | 84 | 5850 |
| Pine Tree | Dickinson | 97.35* | 96 | 2925 |
| Pine Tree | Dickinson | 99.05 | 91 | — |
| ———— | Dickinson | 98.1* | 81.3 | 2700 |
| 22266 No. 2 | Dickinson | 94.5 | 89 | 1800 |
| ———— | Dickinson | 97.35 | 94 | 1800 |
| ———— | Dickinson | 97.15 | 87 | 3150 |
| Freedom | Doughton | 96.6* | 88 | 4950 |
| Freedom A 1015 | Doughton | 96.6* | 90 | 6525 |
| White Mountain | Holbrook | 98.5 | 91.5 | 3150 |
| XXX | Holbrook | 94.3 | 90 | 4500 |
| ———— | Holbrook | 86.5 | 92.5 | 14175 |

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*BELOW GUARANTY. *Alfalfa.* Whitney-Eckstein Seed Company, Buffalo, N. Y.; Grimm; guaranty 99, found 97.1. *Barley.* Albert Dickinson Seed Co., Chicago, Ill.; Six-Row No. 115; guaranty 97.29, found 96. Holbrook Grocery Co., Keene, N. H., etc.; White Mountain; guaranty 99, found 98.5. *Alsike Clover.* E. W. Conklin & Son, Binghamton, N. Y.; C. M.; guaranty 95, found 94.4. Albert Dickinson Seed Co., Chicago, Ill.; Ace; guaranty 95, found 94.2; Pine Tree; guaranty 97.15, found 95.5; Pine Tree 2164; guaranty 97.35, found 96.6; ————; guaranty 98 1, found 97.3. Doughton Seed Co., Jersey City, N. J.; Freedom; guaranty 96.6, found 94.5, 95.8.

†No guaranty reported. See statement on page 30. Figure represents actual analysis.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Liberty | Stanford | 94.71 | 86.5 | 12150 |
| Liberty | Stanford | 97.77 | 85 | 2925 |
| Liberty | Stanford | 94.71 | 85.5 | 8325 |
| Liberty | Stanford | 94.71* | 88.5 | 17100 |
| Fullwerth | Wertheimer | 98.75* | 87 | 5400 |
| ———— | Wertheimer | 98.75* | 91 | 3375 |
| Eureka | Whitney-Eckstein | 98* | 79.5 | 1125 |
| Pan-American | Whitney-Eckstein | 97 | 88.5 | 1125 |
| Pan-American | Whitney-Eckstein | 97* | 94 | 2025 |
| Pan-American | Whitney-Eckstein | 97* | 87.5 | 6300 |
| Pan-American | Whitney-Eckstein | 97* | 85.5 | 2025 |
| Pan-American | Whitney-Eckstein | 97* | 77 | 3150 |
| Pan-American | Whitney-Eckstein | 97 | 93.5 | 2250 |
| Zola | Whitney-Eckstein | 96.33* | 91 | 5850 |
| Supreme | World Seed | 97* | 93.5 | — |
| **RED CLOVER** | | | | |
| Aetna | Conklin | 91.8* | 88.5 | 7200 |
| Crown | Conklin | 99.35 | 94 | 1620 |
| Crown | Conklin | 99.35 | 95.5 | 1440 |
| Paragon | Conklin | 98.25 | 95.1 | 5400 |
| Pine Tree | Craver-Dickinson | 99.6† | 88 | 1440 |
| Pine Tree | Craver-Dickinson | 99.05 | 91 | 540 |
| Ace | Dickinson | 98.9 | 82 | 3240 |
| Ace | Dickinson | 99 | 90 | 2880 |
| Ace 2354 | Dickinson | 98.08 | 87.5 | 1530 |
| Ace 24295 | Dickinson | 98.34 | 91 | 2700 |
| Mammoth | Dickinson | 99.16 | 90.5 | 990 |
| Mammoth | Dickinson | 99 | 91.5 | 990 |
| Medium | Dickinson | 99 | 89 | 630 |
| Pine Tree 24268 | Dickinson | 99 | 91 | 1170 |
| Pine Tree Mammoth 2355 | Dickinson | 99.16 | 90 | 1170 |
| Pine Tree | Dickinson | 99 | 87 | 1080 |
| 74008 | Dickinson | 99.5* | 97 | 1530 |
| Medium | Dickinson | 98.04 | 93.5 | 2070 |
| ———— | Dickinson | 98.9 | 95 | 3060 |
| Extra Fancy | Holbrook | 99.5* | 95.5 | 630 |
| Mammoth | Holbrook | 95 | 86.9 | 6570 |
| White Mountain | Holbrook | 99.5 | 94.5 | 990 |
| White Mountain | Holbrook | 99.5 | 95.5 | 540 |
| XX | Holbrook | 95 | 87.5 | 7020 |
| XXX | Holbrook | 97.3 | 94 | 5490 |
| XXX | Holbrook | 97.3 | 95 | 2970 |
| XXX | Holbrook | 97 | 92 | 4410 |
| ———— | Holbrook | 90* | 89.5 | 15975 |
| ———— | Milwaukee | 97 | 91.5 | 900 |
| Liberty Mammoth | Stanford | 98.28 | 91 | 360 |
| Liberty No. 1 | Stanford | 98.18 | 88.5 | 4950 |

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*BELOW GUARANTY. *Alsike Clover.* Stanford Seed Co., Inc., Buffalo, N. Y.; Liberty; guaranty 94.71, found 94. N. Wertheimer & Sons, Ligonier, Ind.; Fullwerth; guaranty 98.75, found 97.9; ————; guaranty 98.75, found 96.5. Whitney-Eckstein Seed Co., Buffalo, N. Y.; Eureka; guaranty 98, found 97.5; Pan-American; guaranty 97, found 95.6, 96.1, 96.1, 94.6; Zola; guaranty 96.33, found 95.3. *Red Clover.* Albert Dickinson Seed Co., Chicago, Ill.; 74008; guaranty 99.5, found 98.8. Holbrook Grocery Co., Keene, N. H., etc; Extra Fancy; guaranty 99.5, found 98.9; ————; guaranty 90, found 87.8.

†No guaranty reported. See statements on page 30. Figure represents actual analysis.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Liberty | Stanford | 98.28 | 89 | 990 |
| Liberty | Stanford | 98.28 | 88.5 | 810 |
| Liberty | Stanford | 98.5 | 89 | 360 |
| 3678 A | Stanford | 98.8* | 89.5 | 9000 |
| Medium | Stanford | 98.28 | 86.5 | 810 |
| — | Stanford | 95.65 | 84 | 720 |
| Medium | Varick | 98 | 92 | 2610 |
| Fullwerth | Wertheimer | 99.82* | 96 | 810 |
| — | Wertheimer | 99.82 | 97.5 | 1080 |
| Eureka | Whitney-Eckstein. | 99.5* | 94.5 | 1440 |
| Eureka | Whitney-Eckstein. | 99.5 | 95.5 | 270 |
| Eureka | Whitney-Eckstein. | 99.5 | 94.5 | 90 |
| Pan-American | Whitney-Eckstein. | 98 | 92 | 2160 |
| Pan-American | Whitney-Eckstein. | 98 | 97 | 6390 |
| Pan-American | Whitney-Eckstein. | 98* | 85 | 12600 |
| Pan-American | Whitney-Eckstein. | 98 | 93 | 3780 |
| Pan-American | Whitney-Eckstein. | 98 | 96.5 | 900 |
| Pan-American | Whitney-Eckstein. | 98 | 94.5 | 6660 |
| Pan-American | Whitney-Eckstein. | 98 | 90 | 3780 |
| Medium | Whitney-Noyes | 99 | 82.6 | 1170 |
| Supreme | World Seed | 90 | 98 | 17640 |
| | CORN | | | |
| Minnesota King | Bailey | 96 | 87 | — |
| King Philip | Bailey | 95 | 89 | — |
| Gold Nugget | Champlain | 95 | 91 | — |
| Pride of Nishua | Champlain | 95 | 84 | — |
| York State | Champlain | 95 | 94 | — |
| Early Wonder | Conklin | 99.5 | 93 | — |
| Early Wonder | Conklin | 99.5 | 94 | — |
| Improved Leaming | Dickinson | 99.5 | 89 | — |
| Leaming | Dickinson | *99.5*† | 89 | — |
| Longfellow | Dickinson | 99.5 | 98 | — |
| Pride of the North | Dickinson | 99.5 | 95 | — |
| Gold Nugget | Harris | 98 | 86 | — |
| Eureka | Whitney-Eckstein. | 98 | 99 | — |
| Gold Nugget | Whitney-Eckstein. | 98 | 92 | — |
| Gold Nugget | Whitney-Eckstein. | *100*† | 90 | — |
| Gold Nugget | Whitney-Eckstein. | 98 | 96 | — |
| Leaming | Whitney-Eckstein. | 98 | 91 | — |
| Leaming | Whitney-Eckstein. | 98 | 86 | — |
| Longfellow | Whitney-Eckstein. | 98 | 97 | — |
| Pedigree Pride | Whitney-Eckstein. | 98 | 92 | — |
| Early Sanford Flint | Wyman | *99.72*† | 100 | — |
| | MILLET | | | |
| Japanese | Breck | 98 | 92.5 | 1350 |
| Japanese | Breck | 99* | 91 | 4140 |
| German Choice | Conklin | 99.1 | 89.5 | 1980 |
| Japanese | Conklin | 98.2* | 92.5 | 4680 |
| Japanese Pure Quill | Conklin | 97.3 | 93 | 2790 |

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*BELOW GUARANTY. *Red Clover.* Stanford Seed Co., Inc., Buffalo, N. Y.; 3678 A; guaranty 98.8, found 97.2. N. Wertheimer & Sons, Ligonier, Ind.; Fullwerth; guaranty 99.82, found 99.2. Whitney-Eckstein Co., Buffalo, N. Y.; Eureka; guaranty 99.5, found 98.7; Pan-American; guaranty 98, found 93.9. *Millet.* Jos. Breck & Son Corporation, Boston, Mass.; Japanese; guaranty 99, found 98. E. W. Conklin & Son, Binghamton, N. Y.; Japanese; guaranty 98.2, found 96.6.

†No guaranty reported. See statements on page 30. Figure represents actual analysis.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Japanese Pure Quill | Conklin | 97.3 | 95.5 | 3510 |
| Japanese | Conklin | 97 | 94.5 | 3330 |
| Pine Tree | Craver-Dickinson | 97.2 | 91.5 | 3420 |
| Japanese 33125 | Craver-Dickinson | 97.2 | 88.5 | 3690 |
| Japanese | Craver-Dickinson | 98.16 | 93 | 2700 |
| Japanese | Craver-Dickinson | 98.5* | 89.5 | 2880 |
| Japanese | Craver-Dickinson | 98.5 | 94 | 3150 |
| Japanese | Craver-Dickinson | 98.16 | 92 | 2070 |
| Hungarian 80319 | Dickinson | 95 | 86 | 1620 |
| Hungarian | Dickinson | 98.54 | 85.5 | 2610 |
| Hungarian | Dickinson | 98.2 | 77 | 540 |
| Japanese | Dickinson | 98.7* | 96 | 1620 |
| Hungarian XX | Holbrook | 97 | 94 | 900 |
| Hungarian | Holbrook | 95 | 82 | 7110 |
| Hungarian | Holbrook | 97 | 90 | 1260 |
| Japanese | Holbrook | 97 | 89 | 2790 |
| Japanese | Holbrook | 99 | 96.5 | 90 |
| Hungarian 3603 | Stanford | 97 | 82.5 | 3690 |
| Japanese | Stanford | 93 | 80 | 6930 |
| Japanese 3475 | Stanford | 95 | 70‡ | 8550 |
| Japanese Fullworth | Wertheimer | 98.3 | 94 | 3330 |
| Hungarian Fancy | Whitney-Eckstein | 97 | 94 | 1620 |
| Hungarian | Whitney-Eckstein | 98 | 95 | 1620 |
| Hungarian | Whitney-Eckstein | 99 | 92 | 1710 |
| Hungarian | Whitney-Eckstein | 99 | 89 | 2430 |
| Hungarian | Whitney-Eckstein | 98 | 93.5 | 540 |
| Japanese Fancy | Whitney-Eckstein | 97 | 91.5 | 2340 |
| Japanese | Whitney-Eckstein | 97 | 88 | 2160 |
| Japanese | Whitney-Eckstein | 98 | 95.5 | 1080 |
| Japanese | Whitney-Eckstein | 98* | 85 | 5490 |
| Japanese | Whitney-Eckstein | 98* | 93 | 7560 |
| Japanese | Whitney-Noyes | 98 | 79 | 1260 |
| | OATS | | | |
| Pennant | Bailey | 99.5 | 87 | 15 |
| Domestic | Burditt | 98.35 | 97 | — |
| ——————— | Crosby | 99 | 97.5 | 30 |
| Elwood | Cleveland | 99 | 99 | — |
| Northern Wonder | Conklin | 98.1 | 86.5 | 60 |
| Swedish Select | Dickinson | 98.2 | 94 | — |
| Swedish | Dickinson | 99.5* | 99.5 | — |
| Swedish Select | Dickinson | 98.2 | 94 | — |
| Swedish Select | Dickinson | 98.56 | 82 | — |
| Monadnock | Holbrook | 98 | 99.5 | 30 |
| White Mountain | Holbrook | 99 | 92.5 | 15 |
| White Mountain | Holbrook | 99 | 94 | — |
| ——————— | Holbrook | 99 | 98 | — |
| ——————— | Ide | 98* | 93 | — |
| Liberty | Kasco | 98.5 | 98 | — |
| ——————— | Park & Pollard | *97.5*† | 92.5 | 240 |
| ——————— | Webster Tupper | *98.3*† | 95.5 | 45 |

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*BELOW GUARANTY. *Millet.* Craver-Dickinson Co., Buffalo, N. Y; Japanese; guaranty 98.5, found 97.4. Albert Dickinson Co., Chicago, Ill.; Japanese; guaranty 98.7, found 98.2. Whitney-Eckstein Co., Buffalo, N. Y.; Japanese; guaranty 98, found 97.1, 95.7. *Oats.* Albert Dickinson Co., Chicago, Ill.; Swedish; guaranty 99.5, found 96.3. E. T. & H. K. Ide, St. Johnsbury, Vt.; ——————; guaranty 98, found 96.4.

†No guaranty reported. See statement on page 30. Figure represents actual analysis.

‡1921 seed; so indicated on label.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Excelsior | Whitney-Eckstein. | 98 | 79 | 30 |
| Swedish Select | Whitney-Eckstein. | 98 | 83 | 15 |
| ———— | Whitney-Eckstein. | *99.7*† | 84 | — |
| Fancy | Whitney-Eckstein. | 98.5* | 90 | 90 |
| No. 2 White | McEwen | *99.5*† | 99 | — |
| Perfection | ———— | *99.9*† | 91.5 | — |
| | | **RED TOP** | | |
| ———— | Barber & Bennett. | 92.4 | 86.5 | 29250 |
| Imperial | Conklin | 93.3 | 85.7 | 24300 |
| ———— | Craver-Dickinson. | 91 | 81 | 38700 |
| Ace | Dickinson | 90.9 | 90 | 32400 |
| Ace 5870 | Dickinson | 90* | 91.5 | 34200 |
| Ace | Dickinson | 90 | 90 | 20700 |
| ———— | Dickinson | 90 | 90 | 19350‡ |
| ———— | Emerson | *96.54*† | 76.5 | 900 |
| ———— | Holbrook | 80* | 86 | 139050 |
| ———— | Milwaukee | 92* | 83 | 241200 |
| 87806 | Nungessor-Dick. | 90 | 90 | 15750 |
| 87615 | Nungessor-Dick. | 90* | 86.5 | 14850 |
| Ace 87891 | Nungessor-Dick. | 89.6 | 87.5 | 15300 |
| Fancy | Stanford | 81.77* | 89 | 120150 |
| Ace Fancy | Varick | 90 | 94.5 | 20700 |
| Eureka | Whitney-Eckstein. | 92 | 85.5 | 13950 |
| Pan-American | Whitney-Eckstein. | 90 | 91 | 53100 |
| Pan-American | Whitney-Eckstein. | 90 | 88 | 25650 |
| Sagus | Whitney-Eckstein. | 91.1 | 89.5 | 30150 |
| Pan-American | Whitney-Eckstein. | 90 | 89 | 28350 |
| Pan-American | Whitney-Eckstein. | 90 | 88.5 | 35550 |
| | | **TIMOTHY** | | |
| Arrow | Conklin | 99.2 | 96.5 | 1125 |
| Arrow | Conklin | 99.2 | 98 | 225 |
| Bingo | Conklin | 99.9 | 89 | 225 |
| Bingo | Conklin | 99.9 | 96.5 | 1575 |
| King | Conklin | 99.6 | 96 | 450 |
| King | Conklin | *99.7*† | 92 | — |
| King | Conklin | 99.6 | 93.5 | 450 |
| King | Conklin | 99.6 | 95.5 | 675 |
| King | Conklin | 99.6 | 89 | — |
| King | Conklin | 99.6 | 92.5 | 1125 |
| Spear | Conklin | 97 | 91.7 | 10125 |
| Comet | Dickinson | 98.35 | 89 | 2025 |
| B. H. Globe | Dickinson | 99.65 | 98 | 900 |
| Globe 661215 | Dickinson | 99.8 | 95 | — |
| Pine Tree | Dickinson | 99.65 | 95 | 450 |
| Pine Tree 661288 | Dickinson | 99.6 | 91.5 | 675 |
| Pine Tree 66435 | Dickinson | 99.6 | 96.5 | 450 |
| Pine Tree | Dickinson | 99.6 | 97 | — |
| Pine Tree | Dickinson | 99.6 | 95 | — |
| Pine Tree | Dickinson | 99.6 | 88.2 | — |
| Pine Tree | Dickinson | 99.6 | 95 | — |
| Pine Tree 66025 | Dickinson | 99.6 | 94.5 | 450 |

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*BELOW GUARANTY. *Oats.* Whitney-Eckstein Seed Co., Buffalo, N. Y.; Fancy; guaranty 98.5, found 96.6. *Red Top.* Albert Dickinson Seed Co., Chicago, Ill.; Ace 5870; guaranty 90, found 89. Holbrook Grocery Co., Keene, N. H., etc.; ————; guaranty 80, found 79. Milwaukee Seed Co., Milwaukee, Wis.; ————; guaranty 92, found 74. Nungesser-Dickinson Seed Co., New York, N. Y.; 87615; guaranty 90, found 88. Stanford Seed Co., Inc., Buffalo, N. Y.; Fancy; guaranty 81.77, found 81.

†No guaranty reported. See statement on page 30. Figure represents actual analysis.

‡Approximately 50 ergot per gram.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| Pine Tree 66599 | Dickinson | 99.6 | 88 | — |
| Pine Tree 66477 | Dickinson | 99.6 | 95.5 | 900 |
| 66437 | Dickinson | 99.6 | 95.5 | — |
| ———— | Dickinson | *99.7†* | 96 | 225 |
| ———— | Dickinson | 99.5 | 93 | — |
| Pine Tree | Holbrook | *99.65†* | 88.5 | 450 |
| White Mountain | Holbrook | 99.8 | 95 | 225 |
| XX | Holbrook | 98 | 85.5 | 6975 |
| XX | Holbrook | 98 | 90 | 2250 |
| XXX | Holbrook | 99 | 93.5 | 450 |
| ———— | Holbrook | 98 | 92.5 | 2700 |
| Crop Insurance | Milwaukee | 99.5 | 96.5 | 1575 |
| Liberty | Stanford | 99.55 | 95.5 | 225 |
| Liberty | Stanford | 99.5 | 98 | — |
| Liberty | Stanford | 99.5 | 96 | 225 |
| ———— | Stanford | 99.5 | 97.5 | 225 |
| ———— | Stanford | 98 | 92.5 | 2700 |
| Pine Tree | Thomp'n & Hoague | 99.6 | 95.5 | 225 |
| ———— | Varick | 99 | 93.5 | 900 |
| Fullwerth | Wertheimer | 99.8 | 97.5 | 5850 |
| ———— | Wertheimer | 99.8 | 96 | 450 |
| Gold Medal | Whitney-Eckstein. | 99.7 | 91 | — |
| Gold Medal 30202 | Whitney-Eckstein. | 99.75 | 66 | 900 |
| Gold Medal | Whitney-Eckstein. | 99.7 | 93 | 675 |
| Gold Medal | Whitney-Eckstein. | 99.7 | 95.5 | 450 |
| ———— | Whitney-Eckstein. | 99.75 | 56.5 | — |
| Pan-American | Whitney-Eckstein. | 99.5 | 54 | 225 |
| Pan-American | Whitney-Eckstein. | 99.5 | 92 | 675 |
| Pan-American | Whitney-Eckstein. | 99.5 | 93 | 225 |
| Pan-American | Whitney-Eckstein. | 99.5 | 97 | 225 |
| Pan-American | Whitney-Eckstein. | 99.5 | 93.5 | — |
| Pan-American | Whitney-Eckstein. | 99.5 | 91 | 450 |
| Pan-American | Whitney-Eckstein. | 99.5 | 97 | 675 |
| Pan-American | Whitney-Eckstein. | 99.5 | 94.5 | 225 |
| Pan-American | Whitney-Eckstein. | 99.5 | 91.5 | 225 |
| Bond | Whitney-Noyes | 99.55 | 96 | — |
| ———— | Whitney-Noyes | 99.5 | 95 | 450 |
| Supreme | World Seed | 98 | 95.2 | 1250 |
| ———— | ———— | 99.6 | 90.5 | 225 |

## MIXTURES—TIMOTHY AND ALSIKE

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| ———— | Conklin | 85.25 | 75 | 14850 |
| 66808 | Dickinson | 78.2T*<br>15.4A | 81.5 | 9675 |
| ———— | Dickinson | 76.7T<br>15.1A | 83.5 | 11925 |
| ———— | Craver-Dickinson . | 72.6T*<br>17A | 78.5 | —<br>15975 |

## MIXTURE—RED AND ALSIKE CLOVERS

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| ———— | Craver-Dickinson . | 99.25 | 91.5 | 1620 |

## MIXTURES—TIMOTHY AND ALSIKE

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*BELOW GUARANTY. Albert Dickinson Seed Co., Chicago, Ill.; 66808; guaranty 78.2 and 15.4, found 83.9 and 11.5. Craver-Dickinson Co., Buffalo, N. Y.; ————; guaranty 72.6 and 17, found 67 and 21.

†No guaranty reported. See statement on page 30. Figure represents actual analysis.

| Trade name | Wholesaler | Purity guaranty | Germination percent | Weed seeds per lb. |
|---|---|---|---|---|
| MISCELLANEOUS | | | | |
| Buckwheat, Japanese | Conklin | 99 | 98 | 45 |
| Buckwheat, Japanese | Conklin | 99 | 97.5 | — |
| Buckwheat, Japanese | Conklin | 99 | 98 | — |
| Buckwheat (local) | Myers | *98.4*† | 96.5 | 15 |
| Buckwheat, Japanese | Whitney-Eckstein | 98 | 96 | — |
| Buckwheat, Japanese | Whitney-Eckstein | 98 | 92.5 | — |
| Clover (Sweet) | Dickinson | 98.38 | 81.5 | 3420 |
| Clover (Sweet) 2555 | Stanford | 97.97 | 72.5 | 360 |
| Clover (White) Henry | Stanford | 97.85 | 83 | 8325 |
| Clover (White) 2648 | Stanford | 95 | 85 | 12825 |
| Clover (White) —— | Stanford | 96.1* | 91 | 8100 |
| Orchard Grass P. I. | Dickinson | 80.9 | 54 | 19800 |
| Orchard Grass 5221 | Dickinson | 69.2* | 59.5 | 2025 |
| Orchard Grass | Dickinson | 85 | 69.5 | 1800 |
| Orchard Grass 87589 | Nungessor-Dick | 87.45 | 42 | 2475 |
| Orchard Grass | Whitney-Eckstein | 83.9 | 58.5 | 2025 |
| Peas (Canada Field) | Conklin | 99* | 95 | — |
| Peas (Canada Field) | Conklin | 99 | 95.5 | — |
| Peas (Canada Field) | Whitney-Eckstein | 98 | 89 | — |
| ———— | Whitney-Eckstein | 98 | 82 | — |
| Rape | Holbrook | 99.82 | 98.5 | — |
| Rape | Whitney-Eckstein | 98 | 100 | — |
| Rape | Whitney-Eckstein | 98 | 100 | — |
| Rye (Spring) | Ide | 96.42 | 90 | 45 |
| Rye (Spring) | Whitney-Eckstein | 98* | 98 | 30 |
| Rye (Winter) | Whitney-Eckstein | 98* | 68 | 15 |
| Rye (Spring) | Whitney-Eckstein | 98* | 90 | 960 |
| Soya Beans (Yellow) | Whitney-Eckstein | 98 | ‡ | 18 |
| Speltz | Whitney-Eckstein | 98 | 69.5 | — |
| Sudan Grass | Dickinson | 98.01* | 87 | — |
| Sudan Grass | Whitney-Eckstein | 97 | 67 | 540 |
| Sudan Grass | Whitney-Eckstein | 98 | 77 | 720 |
| Sudan Grass | Whitney-Eckstein | 97 | 69 | 450 |
| Sudan Grass | Whitney-Eckstein | 98 | 77.5 | — |
| Sudan Grass | Whitney-Eckstein | 97 | 69 | 450 |
| Sudan Grass | Whitney-Eckstein | 97 | 68 | 630 |
| Vetch | Whitney-Eckstein | 98 | 37 | — |
| Wheat (Spring) Marquis | Dickinson | 98.74 | 97.5 | 75 |
| Wheat (Spring) | Whitney-Eckstein | 98 | 94 | — |
| Wheat (Spring) | Whitney-Eckstein | 98 | 95.5 | 30 |
| Wheat (Spring) | Whitney-Eckstein | 98 | 97.5 | 45 |
| Wheat (Spring) Marquis | Whitney-Eckstein | 98 | 96.5 | — |

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*BELOW GUARANTY. *White Clover.* Stanford Seed Co., Inc., Buffalo, N. Y.; ————; guaranty 96.1, found 95.5. *Orchard Grass.* Albert Dickinson Seed Co., Chicago, Ill.; guaranty 69.2, found 48. Whitney-Eckstein Company, Buffalo, N. Y.; ————; guaranty 90, found 83.9. *Peas.* E. W. Conklin & Son, Binghamton, N. Y.; guaranty 99, found 97. *Rye.* Whitney-Eckstein Co., Buffalo, N. Y.; guaranty 98, found 92.5, 96.4, 93.8. *Sudan Grass.* Albert Dickinson Seed Co., Chicago, Ill.; guaranty 98.01, found 97.4.

†No guaranty reported. See statement on page 30. Figure represents actual analysis.

‡Not tested.

## DISCUSSION OF THE RESULTS OF INSPECTION

The violations of the law consist of:

(1) *Failure to declare guaranties.* This amounts to practical nullication, in so far as information touching guaranteed purity supplied to the purchaser of the usual amounts from broken packages is concerned. The writer has no means of knowing with certainty but has every reason to believe that local merchants quite commonly fail to affix "a plainly written or printed statement," "conspicuously" to "every lot or parcel of agricultural seed of five pounds or over sold for seeding purposes" "clearly and truly certifying the namer thereof and its minimum percentage of purity," etc.

Nearly five percent of the lots sampled by the station agents bore no visible statement as to the purity of their contents. Almost invariably this information is furnished by the wholesaler, but the retailer often pays no attention to and destroys it.

(2) *Failure to maintain guaranties.* Seventeen percent of the goods which were guaranteed were found to be deficient—one in six—and three percent were seriously deficient. Especial attention is called to the cases noted below. It is not surprising that there are several lapses in view of the extremely tenuous protection afforded by the Vermont law, which is about as toothless as it well can be.

*Craver-Dickinson Seed Co., Inc., Buffalo, N. Y. Timothy and Alsike;* guaranty 72.6 and 17, found 67 and 21. The trouble here is one of distribution, the timothy overrunning and the alsike underrunning the guaranty. It is possible that mechanical separation occurred in the sack and that it really contained the proportions indicated.

*Albert Dickinson Seed Co., Chicago, Ill. Alsike Clover;* Pine Tree 2164; guaranty 97.15, found 95.5. This sample contained 5,850 weed seeds per pound, mostly yellow trefoil and catchfly, in addition to many timothy and white clover seed. It contained 3.5 percent foreign seed.

*Albert Dickinson Seed Co., Chicago, Ill. Oats;* Swedish; guaranty 99.5, found 96.3. This sample contained 3.4 percent foreign seed, mostly barley with some wheat.

*Albert Dickinson Seed Co., Chicago, Ill. Orchard Grass;* 5221; guaranty 69.2, found 48. This sample contained no less than 51 percent inert matter.

*Albert Dickinson Seed Co., Inc., Chicago, Ill. Timothy and Alsike;* guaranty 78.2 and 15.4, found 83.9 and 11.5. The trouble here is one of distribution.

*Milwaukee Seed Co., Milwaukee, Wis. Red Top;* guaranty 92, found 74. This sample carried 241,200 weed seeds per pound, approximately ⅔ of them being five-finger, ⅙ black-seeded plantain and ⅙ sedges and yarrow. It also contained a heavy percentage of timothy. The sample showed 74 percent pure seed, 9 percent foreign seed, 17 percent inert matter.

*Whitney-Eckstein Company, Buffalo, N. Y. Red Clover; Pan-American;* guaranty 98, found 93.9. This sample carried 12,600 weed seed per pound, approximately ⅔ of them buckthorn and ⅓ green foxtail. It also contained much timothy and alsike. More than 1/20 of the entire weight consisted of seed other than red clover.

*Whitney-Eckstein Company, Buffalo, N. Y. Orchard Grass;* guaranty 90, found 83.9. One-seventh of this sample was inert matter.

*Whitney-Eckstein Company, Buffalo, N. Y. Spring Rye;* guaranty 98, found 92.5 and 93.8. The first sample carried more than 5 percent foreign seed, buckwheat and wheat, and the second a similar amount, mostly wheat and, in addition, a fair sprinkling of weed seed, all of it field bindweed.

## CONCERNING VIABILITY

The Vermont law does not require the seller to state the viability of his goods—as is done in New Hampshire, New Jersey and several other states. However, the Vermont Station has always reported upon this important matter. A considerable number of lots bore a guaranty statement as to viability. It is interesting to compare promise and performance, as follows:

| | Total number | Guaranteed | Guaranty met | Guaranty not met |
|---|---|---|---|---|
| Alfalfa | 9 | 8 | 2 | 6 |
| Barley | 12 | 10 | 7 | 3 |
| Clover, alsike | 36 | 24 | 12 | 12 |
| Clover, red | 52 | 40 | 22 | 18 |
| Corn | 21 | 11 | 8 | 3 |
| Millet | 37 | 32 | 16 | 16 |
| Oats | 23 | 10 | 4 | 6 |
| Red Top | 21 | 15 | 7 | 8 |
| Timothy | 61 | 37 | 32 | 5 |
| Mixtures | 5 | 4 | 1 | 3 |
| Miscellaneous | 42 | 27 | 15 | 12 |
| | 319 | 218 | 126 | 92 |

Dealers are rapidly coming to guarantee their goods. This is due to the fact that such a guaranty is required in several states. Last year only one in three lots were guaranteed as to their viability, whereas this year two in three are thus labeled. Last year 3/5 of the guaranties were made good in fact and 2/5 were not; and the proportions this year are the same.

How is it as between the different seed houses? Eighty-five percent of the samples represent the product of six concerns and 50 percent that of two houses. Four of these six sellers guaranteed the viability of practically all the goods bearing their names. The guaranties were maintained in two cases out of three with three of these companies and in one in two with one of them. One concern, selling very widely throughout Vermont, guaranteed 2/3 of the lots which were offered and 1/3 of these guaranties were not maintained. Another house, likewise a very large seller, guaranteed only one lot in five and the guaranties of one-half of these few were not made good.

COMPARISON OF VIABILITY WITH STANDARDS

| Seed | Standard of viability | Samples | Up to or above minimum standard | Below minimum standard |
|---|---|---|---|---|
| Alfalfa | 85-90 | 9 | 3 | 6 |
| Barley | 90-95 | 12 | 8 | 4 |
| Alsike clover | 75-80 | 36 | 36 | 0 |
| Red clover | 85-90 | 52 | 49 | 3 |
| Corn | 90-95 | 21 | 15 | 6 |
| Millet | 85-90 | 37 | 32 | 5 |
| Oats | 90-95 | 23 | 19 | 4 |
| Red top | 75-80 | 21 | 21 | 0 |
| Timothy | 85-90 | 61 | 58 | 3 |
| Buckwheat | 90-95 | 5 | 5 | 0 |
| Peas | 93-98 | 4 | 2 | 2 |
| Rape | 90-95 | 3 | 3 | 0 |
| Rye | 90-95 | 4 | 3 | 1 |
| | | 288 | 254 | 34 |

This outcome, on the whole, is a reasonably satisfactory one, 7/8 of the lots being of standard quality in respect to viability. Apart from the matter of guaranty maintenance, it may be said that viabilities on the whole were quite good, as judged by the samples drawn in 1922. Buyers should note, however, that the alfalfa as a whole was not of a standard quality and should observe the particularly low figures pertaining to orchard grass.

OCTOBER, 1922 BULLETIN 229

University of Vermont and State Agricultural College

# Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# THE PROTEIN AND THE MAINTENANCE REQUIREMENTS OF DAIRY CATTLE

By J. L. HILLS

*(Popular Edition of Bulletins 225 and 226)*

BURLINGTON
FREE PRESS PRINTING COMPANY
1922

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# BULLETIN 229: THE PROTEIN AND THE MAINTENANCE REQUIREMENTS OF DAIRY CATTLE

(Popular edition of Bulletins 225 and 226)

BY J. L. HILLS

## INTRODUCTION

The dairy cow uses protein in part to maintain her bodily status. She uses it in part but not largely to construct the fœtus. She uses it in part in milk making. Perhaps she uses it to some extent as a stimulus to milk making. In other words, from the protein in her food she builds nitrogenous tissue—the muscles, tendons, cartilagineous materials, etc.—or replaces the wastage necessarily incident to the usage of such tissue; she constructs fœtal structure; she places casein and albumin in the milk; and, perhaps, as a result of an over-plentiful supply, may make more milk. Now protein costs money and its over-usage is to be decried. Enough is said to be as good as a feast. What is enough protein? How much can a cow use to advantage? How little can she get along with? What are the economic metes and bounds in protein usage in dairy feeding?

How much food does a cow need to keep herself alive, how much digestible protein and digestible carbohydrates and fat are used, how many calories of energy are thus employed? How much is needed by a dry farrow cow, by a pregnant cow in milk? How much food is used in milk making, in the construction of the fœtus, in the maintenance of the animal body?

These pertinent questions were asked in 1906 by the writer and his former associate, the station animal and dairy husbandman, Prof. Chas. L. Beach, for the past 14 years President of the Connecticut Agricultural College. There had been considerable experimentation dealing with these matters which sought to answer these questions, but they were not settled. They were vital questions. It seemed worth while still further to study them. Hence trials were started which ran for twelve and one-half years. Since 1906 much fundamental work has been done in this and other countries along these lines and several contributions to the study of protein and maintenance needs have been made. None of these trials have lasted as long or in some respects have been as comprehensive as the Vermont trials. The work done here has not settled matters for all time. Further work is now under way at this Station and the problems are being intensively studied elsewhere. It is felt, however, that appreciable advance has been made in our knowledge as to protein usage and maintenance needs as a result of the twelve and one-half years' work.

## THE TWELVE QUESTIONS AS TO PROTEIN USAGE

It was hoped that the so-called protein trials would throw light on 12 points, namely:

1. The effect wrought upon the milk flow by the long continued use of rations carrying either very low, or relatively low, or medium, or high digestible protein contents.
2. The physical condition, the health, the continued well-being of cows fed on a uniform diet for a long series of years, e. g., a relatively low digestible protein ration or a relatively high digestible protein ration.
3. The relation which rations carrying very low, or low, or medium, or high digestible protein contents might bear to changes in the body weights of milking cows.
4. The immediate effects upon the milk flow of rations carrying either very low, low, medium or high digestible protein contents, as determined by means of trials of short duration.
5. The results obtained in feeding trials conducted for many months or years as compared with those secured in trials of shorter duration.
6. The relation between the digestible nutrients in the food and those accounted for in maintenance and milk flow, when rations were fed differing widely in their digestible protein contents.
7. The validity of existing feeding standards.
8. The effect upon the quality of the milk flow secured when rations were fed which contained widely divergent digestible protein contents.
9. The economics of milk and butter production when rations were fed which were decidedly unlike in their digestible protein contents.
10. The normal shrinkage in bovine milk flow.
11. The extent of the direct injury to the milk flow caused by abortion.
12. The effect upon the milk flow of abrupt changes in rationing.

## THE QUESTIONS AS TO MAINTENANCE USAGE

It was hoped that the so-called maintenance trials would furnish information as to the nutrient usage by:

(1) Dry farrow cows.
(2) Dry pregnant cows.
(3) Non-pregnant milking cows.
(4) Pregnant milking cows.

## CONDUCT OF THE TRIALS

The trials lasted twelve and one-half years; 119 individual cows were used; and the equivalent of nearly 550 years of cow life were employed, that is to say, the equivalent of 550 cows fed one year or one cow—she would have been a veritable bovine Methuselah—fed 550 years.

Four rations were fed, which were meant respectively to carry per 1,000 pounds of live weight, approximately, 1 pound, 1.5 pounds, 2 pounds and 2.5 pounds of digestible protein. They were known as the very low, low, medium and high protein rations. The four rations were meant to carry—and as a matter of fact did carry—approximately equivalent amounts of total digestible nutrients.

Some of the cows were fed the same ration, e. g., the low protein ration, continuously day in and day out, summer and winter, for as many years, whether one or ten, as they remained in the trials. Others were fed during one lactation on one ration, e. g., the low protein ration and during the next on some other, e. g., the high protein ration, to return during the next lactation to the one first fed. Other cows were thus alternated from one to the other ration every five weeks. Still other cows in the maintenance group were so handled as to be held dry for great lengths of time and under divers circumstances. Hay, silage and definite grain rations (wheat bran, ground oats, corn and cob meal, hominy feed, gluten feed, cottonseed and linseed meals) were fed. Constant analytical check was kept upon the nutrient usage and milk and milk constituent yields of each cow. More than 300,000 milk weights were made; more than 1,000,000 weights of fodders and feeds; many tens of thousands of milk samples taken; many thousands were analyzed; many thousands of fodders and feeds were analyzed. The computational work was stupendous. The mere paper and ink of the records and computations when the trials were about two-thirds through, weighed 301 pounds.

## THE CONCLUSIONS

Now what answers were secured to the questions which the writer and his former associate put to themselves 16 years ago this fall? What conclusions may be safely drawn from the study of the results of these long continued trials? The work was not conclusive in all respects, it was not without error or lapse in several respects in its conduct, yet the volume of the work, the large number of animals employed, the careful control kept from the very outset and the extreme length of the trials, are factors which ought to have weight and doubtless contribute to the essential accuracy of the outcome.

## CONCLUSIONS AS TO PROTEIN REQUIREMENTS

The summation of the results in respect to the protein trials appear on pages 143-146 of bulletin 225 and are restated below:

1. *What effect was wrought upon the milk flow by the long continued use of rations carrying either very low, or relatively low, or medium, or high digestible protein contents?*

The results which were secured in the long term trials seem to justify the statement that for some years at least a ration carrying a pound of digestible protein a day per 1,000 pounds live weight may serve the purposes of a not over heavy milking cow, enabling her to yield a reasonable, though obviously not a large, amount of milk. With a full assurance of certainty this can be said of the use of a ration carrying 1.5 pounds of digestible protein per day per 1,000 pounds live weight. A ration carrying 2 pounds of digestible protein a day per 1,000 pounds of live weight may enable a cow to yield a very little more milk than the two rations above indicated. It is quite unnecessary for milk making purposes to increase the digestible protein content of the ration to 2.5 pounds per day per 1,000 pounds of live weight.

2. *What effect was wrought upon the physical condition and health of the cows which were fed on a uniform diet for a long series of years? Was either a relatively low digestible protein content on the one hand or a relatively high digestible protein content on the other inimical to their continued well-being?*

The cows which were continuously fed for upwards of 4½ years on the very low digestible protein ration, the intake being barely a pound daily per 1,000 pounds live weight, were not injured in respect to their physical condition, in so far as the same could be determined by careful survey. This general statement holds for each of the 10 cows thus continuously fed. Neither is there definite information in hand to warrant the assertion that the continued feeding of the high protein ration, 2.5 pounds digestible protein a day per 1,000 pounds live weight, was in any respect injurious. Yet it is interesting to note, though probably in nowise significant, that, speaking broadly, the cows to which this high proteinous ration was fed tended to drop out of the trials earlier, to last a shorter time than those fed the medium protein (2 pounds) or low protein (1.5 pounds) rations. The writer lays no stress upon this fact—but it is a fact.

3. *What relation did rations carrying very low, or low, or medium, or high digestible protein contents bear to changes in the body weights of milking cows?*

The cows which were continuously fed for upward of 4½ years on the very low digestible protein ration, tended to lose live weight, averaging an 8 percent loss, maintaining their milk yields at the expense of body weight, their losses, however, being not sufficient to induce emaciation or unthriftiness. The cows which were fed the low and the medium digestible protein rations tended to gain in body weight until approximately 10 years of age. The cows which were fed the high protein ration put on relatively little live weight and tended as a whole slightly to lose in weight after the seventh year.

4. *What were the immediate effects upon the milk flow of rations carrying either very low, low, medium or high digestible protein contents, as determined by means of trials of short duration?*

The results which were secured in the short alternation trials seem to justify the statement that the high protein ration averaged to make 3.5 percent more product than the low protein, and 2 percent more than the medium protein ration, and that the latter made 2.5 percent more than the low protein ration.

5. *Were the results obtained in feeding trials conducted for many months or years comparable with those secured in trials of shorter duration?*

On the whole the results secured in short alternation trials may be expected to be reasonably parallel to those afforded by long-time experiments, provided the former are carefully planned, well executed and the number of animals used is ample.

6. *What was the relation between the digestible nutrients in the food and those accounted for in maintenance and milk flow, when rations were fed differing widely in their digestible protein contents?*

The digestible protein utilization in milk making varies profoundly with ration changes in respect to this nutrient. Carbohydrate utilization similarly varies but inversely to and less profoundly than protein. In several instances, using the old time 0.7 pound digestible protein maintenance allowance, recovery exceeded 100 percent. Protein recovery was essentially identical for thin milking and for rich milking cows.

7. *What may be said, in the light of the results in these trials secured, touching existing feeding standards?*

Existing feeding standards are plentiful in number and some of them are reasonably satisfactory. The outcome of these trials tends to substantiate those standards which suggest somewhat lower digestible protein needs than were set forth a generation ago; and the vast amount of data in bulletin 226—dealing with "The Maintenance of Dairy Cattle" likewise tends to uphold this statement.

8. *Was the quality of the milk flow altered when rations were fed which contained widely divergent digestible protein contents?*

The total solid and fat contents of the several milks were unaffected by the changes in rationing, but to a slight extent their albuminoid contents were changed in a direction parallel to the increase or decrease in the protein content of the ration.

9. *What can be said touching the economics of milk and butter production when rations were fed which were decidedly unlike in their digestible protein contents?*

The vagaries of the American feed markets are such that it is quite impossible dogmatically to assert that any one of the four rations fed, or any other constructed with a view of furnishing equivalent amounts of digestible protein and total digestible nutrients, necessarily is always to be preferred—viewed from the standpoint of economics. However, as things were in pre-war days, there was but little to choose between them, whereas nowadays the high protein ration is inordinately costly as compared with the medium or low protein rations. This is doubtless in part a reflex of the abundant corn crop of 1921 and its consequent low price. However, it should always be borne in mind that, other things being equal—they are far from being equal at present—so be it prices are not materially unlike, a relatively nitrogenous ration is to be preferred to one carrying a smaller proportion of protein, because of its increased content of plant food.

10. *What is the normal shrinkage in bovine milk flow?*

The testimony which was afforded by 305 complete lactations indicated that cows bred to calve 12 to 14 months after calving tend to give month by month $\frac{9}{10}$ of the yield of the preceding month for nine months and $\frac{5}{6}$ of the yield of the preceding month during the remainder of their lactation. Cows which have aborted or which remain farrow tend to give month by month $\frac{13}{14}$ of the yield of the preceding month. These factors are closely similar to those heretofore published. This large amount of data simply adds to the present stock of information; which was all that it was expected it would do.

11. *To what extent is the milk flow directly affected by abortion?*

As a result of abortion (28 cases having occurred) the average milk flow was decreased for ¼ to ⅕ and the total solids, fat and albuminoid percentages increased about 0.20 percent.

12. *What effect upon milk flow is wrought by abrupt changes in rationing?*

Based upon the comparison of 394 instances of abrupt changes in rationing, the statement seems warranted that, provided no material alteration occurs in the digestible nutrient intake, abrupt changes in the digestible protein intake are not likely to be reflected in the milk yields.

### CONCLUSIONS AS TO MAINTENANCE REQUIREMENTS

The answers to the questions as to maintenance needs of dairy cattle in various stages of life, while dry, while pregnant, while farrow, while milking, are summarized on pages 182-184 of bulletin 226. The essential findings may be stated as follows:

*Dry, non-pregnant cows.* It seems reasonably safe to conclude that a daily digestible nutrient intake of 0.5 pounds true protein—or its equivalent of 0.6 pounds digestible crude protein—and of 6 therms of energy—or its equivalent of 0.5 pounds total digestible nutrients—is sufficient to maintain a 1,000 pound dry, non-pregnant cow. These are the figures proposed by Armsby and by Eckles.

*Fœtal construction.* It seems quite safe to assume that fœtal construction makes little or no draft upon the non-nitrogenous nutrient intake of the mother, but a small but noticeable draft upon her digestible protein intake, equivalent to a daily usage of from 0.05 to 0.1 pounds which may amount to upwards of 10 percent of the entire protein intake extending over the entire gestation period, very much the larger part of which draft, of course, occurs during the latter part of gestation.

*Milk making.* It seems quite safe to assert that a pound of digestible protein a day per 1,000 pound live weight is not enough to enable a cow to make a full milk yield, to drop a full-sized calf and to maintain her full live weight. It is very certain that a 2½ pound digestible protein supply is entirely unnecessary, neither increasing milk flow materially nor augmenting live weight over those secured when a lesser amount is fed. Apparently a 1½ pound digestible protein intake per 1,000 pounds of live weight enabled the cows in these trials to make reasonably good yields, drop healthy and full sized calves and maintain their bodily status. It should be said, however, that most of the cows in these trials were fed on a somewhat overhigh plane of nutrition.

So far as the current feeding standards are concerned it may be said that the vast amount of data accumulated seems to warrant the assertion that no one of them is ideal, the Savage figures tending to run high and the Armsby figures tending to run low, the Haecker (1914) figures to be reasonably satisfactory in respect to digestible protein and the Eckles figures to be reasonably satisfactory though somewhat low for milks below 5½ percent fat.

*Milk making by pregnant cows.* It seems safe to conclude that during the first two-thirds of gestation, a ration furnishing standard amounts of the several nutrients for purposes of maintenance and milk only should serve the third purpose, that is to say the early stages of fœtal construction; and that during the last third of the gestation, when usually either a small amount of milk is being made or none whatever, according to the amount made, there should be fed a maintenance ration plus the amount needed for milk making and plus the equivalent of, perhaps, twice the total digestible nutrient content of the newborn calf, care being taken to see to it that this increment contains a sufficiency of digestible protein upon which ingredient the fœtus makes an especial draft. All of which, "being interpreted" means; do not forget the call of the unborn calf, and feed a little more liberally than is needed to maintain the mother.

*The full statements concerning these trials as set forth in bulletins 225 and 226, containing respectively 200 and 192 pages, are free for the asking.*

APR 2

MARCH, 1923 BULLETIN 230

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# CONCERNING BLOOD COMPLEMENT

*By* F. A. RICH
*Former Station Veterinarian*

BURLINGTON
FREE PRESS PRINTING COMPANY
1923

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# BULLETIN 230: CONCERNING BLOOD COMPLEMENT

By F. A. Rich*

Former Station Veterinarian

In connection with the titration of guinea pig's blood serum for use in biological tests at the Vermont Station the writer found, in 1913, a sample of serum in which no complement could be detected. Further trials were made in which increasing amounts up to 1 c. c. were used with the same negative result; and this result was abundantly confirmed in the station as well as in other laboratories and by several workers. So far as the writer is aware a similar situation had not been met elsewhere at that time.[1] At any rate, he did not find published mention of the fact, although, it is true, his search of literature was not exhaustive. In view of the fact that guinea pig blood constitutes the main laboratory source of complement and that it has been generally assumed[2] that all cavies possessed this character, its deficiency in this instance was both striking and disconcerting.

Complement has been deemed in the past to be a normal and invariable constituent of blood serum. It is held to be a protective agency because of its destructive activities in respect to invading organisms, after the latter have been sensitized by the amboceptor which the somatic cells produce as a result of the antigenic action of the invader. It brings about disintegration of foreign blood cells as soon as the latter provide the necessary and specific amboceptor by their antigenic action on the body cells. Theory has it that complement guards the body against serious inroads by pathogenic organisms, that it aids in the combat against established and well-seated infection and that it tends in a way to supplement the combative activities of antitoxins, serums and vaccines. In short, complement is held to be a necessary factor in bacteriolytic immunity in respect to infection.

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*The writer acknowledges the helpful cooperation of the late Ramon C. Downing, M. Sc., associate veterinarian 1914-1917, and Hiram D. Moore, A. B., M. Sc., associate veterinarian 1917-1919, now Professor of Bacteriology in the University of Oklahoma. Mr. Downing assisted more particularly in the conduct of the genetic studies and most faithfully cared for the many thousands of experimental animals. Professor Moore is responsible in large measure for the study of the inter-relationships of the opsonins and complement.

[1] See Schlesinger's statement (1915) cited on page 15.

[2] Noguchi seems to have assumed unerring uniformity in the amount of complement from this source when he advised the use of 0.1 c. c. of 40 percent fresh guinea pig's serum in the complement fixation test, without requiring complement titration. (Serum Diagnosis of Syphilis, 3rd edit. Chap. 7 [1912].)

Sajous states that "complement is always present in normal serum." (Analytic Cyclopedia of Practical Medicine [7th edit.]. Vol. V., p. 386 [1913].)

Zinsser speaks of complement as "universally present in normal serum" (Infection and Resistance).

The chemical characteristics, the physical characteristics, the very nature of complement is not known. What it does is evident but what it is is not clear. It acts in some respects after the fashion of an enzym but in others it does not. It is readily destroyed by a half hour's heating at 50° C. and rapidly deteriorates as to its potency on standing either at room temperature or in cold storage. Whether there is more than one such substance in a given serum was a moot point for a time and is not yet determined with absolute certainty, but later studies have seemed to indicate that there is but one.

The importance of complement in connection with the complement-fixation test, its accredited relation to the establishment of acquired immunity to infectious diseases, as well as the possibility that its omission may occur more frequently in nature than is generally supposed and, finally, the possible relation of its comparative lack to increased susceptibility to the inroad of infectious disease; all these conditions seemed to warrant thorough investigation of the case in hand.

And such an investigation has been conducted at this Station for a considerable period of years, during which time attempts have been made in part at least to answer the following questions:

1. Was this complement-deficient strain mutant?
2. If so, do breeding experiments show that it conforms to Mendel's law?
3. Is complement a constant or a variant character of the blood serum?
4. Are complement-deficient guinea pigs more susceptible to disease than are complement-positive guinea pigs?
5. What is the relation of complement to opsonins?
6. What is the opsonic index of complement-negative sera?
7. Do complement-deficient sera possess hemolytic or bacteriolytic powers?
8. Can complement production be induced in complement-deficient guinea pigs?

## GENETIC STUDIES

The guinea pig which furnished the unusual serum mentioned on page 3 was from the stock of the Vermont State Laboratory of Hygiene, being one of a recent consignment purchased direct from a breeder of cavies in Middlesex, Vt. The source from which this party secured the parent stock could not be determined.

It seemed highly probable that mutation had occurred and that this low complement individual was either a mutant or a member of a mutant strain, although the possibility that it was a sport could not be entirely ignored. Since only a dominant mutant would display the new character and since this form of mutation is less common than the recessive type, it seemed reasonable to assume that a recessive mutation had occurred at least two generations back, thus permitting the recessive character to appear in this animal. Such a hypothesis, however, necessitated the assumption that two hybrids, genotypically identical with the original mutant, had appeared in the breeder's stock for every recessive animal dropped.

Fifty-one animals (12 males, 39 females) were secured from this breeder and from the State Laboratory, numbered, ear-tagged and detailed individual descriptions recorded. It was a random selection in each case. Bleeding, followed by the usual complement titration,[1] disclosed a three to one ratio respecting the contrasted complement phenotypes but a striking disproportion of sexes (6 male, 32 female) obtained in connection with the high complement character. Thirteen individual sera caused no hemolysis in 0.2 c. c., 20 percent solution, while the remaining 38 sera gave complement titres ranging from 0.07 to 0.04 c. c. with an average of 0.058 c. c. The 13 (6 male, 7 female) were again bled and their sera subjected to a yet more rigid test, in which amounts of the 4 to 1 dilution up to 1 c. c. were used and comparable results secured.

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[1] The hemolytic system employed at the time the complement-deficient animals were discovered comprised horse erothrocytes and anti-horse amboceptor, produced by immunizing rabbits to the horse blood cells. The amboceptor was titrated to ½ c. c. of 1 percent suspension of the horse erothrocytes in the presence of an excess of complement. Two or more units of the amboceptor were used in all the complement tests and titrations.

A sheep hemolytic system was used parallel with the horse system on more than 300 complement-deficient sera with equally good results, but a human hemolytic system tried on a limited number of sera gave very different results, for while it indicated a deficiency of complement in all sera titrated the deficiency shown was far less marked than with the horse system.

A convenient and accurate method of preserving standardized bacteriolytic amboceptors against deterioration was devised during the course of the study. Having been drawn in the usual way, 10 x 10 cm. squares of S. and S. filter paper No. 597 were saturated with the serum, being evenly wet throughout, placed on non-absorbent paper, dried at room temperature, cut into 10 m. m. strips and standardized as to their amboceptor content. Small pieces varying in width from 1 to 5 m. m. were cut from the end of a 5 x 100 m. m. strip and added to a series of tubes containing the same amounts of other factors as those employed for the titration of the liquid serum. After a half hour's incubation at 37° C. the narrowest piece causing complete hemolysis was found to measure 2 m. m. and that was assumed as the amboceptor unit. The strips were placed in dry, corked, paraffin-sealed test tubes and stored in the dark. At an interval of nine months the titre remained unchanged. Indeed, after six years the titre was sufficient to enable its use as a control. The obvious advantages of this procedure are uniformity, ease of preservation for a long period without perceptible change of titre, and the fact that the strip does not need to be inactivated to destroy the complement.

Mutation had seemed very acceptable as an explanation of the origin of one such case, but the finding of 13 similar cases in the same breeding stock left no room for doubt as to the adequacy of such an explanation. The fundamental nature of the problem now seemed clear, but its solution obviously involved the production of a sufficiently large population, possibly thousands of individuals, by carefully controlled pedigreed breeding to enable a definite determination of the genetic constitution responsible for the contrasted characters. Unlike most Mendelian studies the breeding test must be supplemented by a delicate serological test, because both the Mendelian factor and the character conditioned by it are hidden from view, one in the blood stream of the soma and the other in the germoplasmic stream which courses through the successive generations.

The sexes were segregated to prevent further chance mating and to allow the females already pregnant from such mating to drop their young. The 51 breeding animals were then divided into two groups to enable a preliminary trial mating. Group I contained 5 low complement females, 20 high complement females and 6 low complement males; group II, 12 high complement females, 2 low complement females and 6 high complement males. The object of this grouping and mating was to determine whether the low or the high complement condition was dominant in transmission; for while the preponderance of high complement individuals seemed to indicate their condition to be controlling, such prevalence could also be accounted for by a very recent dominant mutation, in which case the low complement condition should be dominant provided perfect dominance obtained.

While the complement test clearly divided the animals into two distinct phenotypical classes it seemed reasonable to assume that, according to the direction of dominance, either one or the other of these classes, in reality, comprised two distinct genotypical kinds, one of them homozygous for its complement condition, the other heterozygous for the same. This assumption, however, needed confirmation. Because of this uncertainty as to the genotypical constitution of the individuals, all the complement-deficient males were allowed to run with the females in group I and all the males apparently normal in respect to complement were employed for mating in group II. However, all the females in both groups were placed in individual pens before dropping their young.

Table I sets forth the offspring resulting from each of the different matings in the two groups.

TABLE I. ORIGINAL MATINGS, 1913

| | Group I | | | | | | Group II | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Parents | | | Offspring | | | Parents | | | Offspring | |
| | Female | | Male | | | | Female | | Male | | |
| 1 | c | X | c | c | c | 27 | C | X | C | C | |
| 2 | c | X | c | c | c | 28 | C | X | C | C | |
| 3 | c | X | c | c | c | 29 | C | X | C | C | C |
| 4 | c | X | c | c | | 30 | C | X | C | c | |
| 5 | c | X | c | c | c | 31 | C | X | C | C | C |
| 6 | C | X | c | C | c | 32 | C | X | C | C | C |
| 7 | C | X | c | C | C | 33 | C | X | C | C | C |
| 8 | C | X | c | C | C | 34 | C | X | C | C | C |
| 9 | C | X | c | C | c | 35 | C | X | C | C | C |
| 10 | C | X | c | C | C | 36 | C | X | C | C | C |
| 11 | C | X | c | C | C | 37 | C | X | C | C | C |
| 12 | C | X | c | C | | 38 | c | X | C | C | c |
| 13 | C | X | c | c | c | 39 | c | X | C | | |
| 14 | C | X | c | C | c | | | | | | |
| 15 | C | X | c | C | C | | | | | | |
| 16 | C | X | c | C | c | | | | | | |
| 17 | C | X | c | C | C | | | | | | |
| 18 | C | X | c | C | c | | | | | | |
| 19 | C | X | c | C | c | | | | | | |
| 20 | C | X | c | C | | | | | | | |
| 21 | C | X | c | C | c | | | | | | |
| 22 | C | X | c | C | C | | | | | | |
| 23 | C | X | c | c | c | | | | | | |
| 24 | C | X | c | C | C | | | | | | |
| 25 | C | X | c | | | | | | | | |
| 26 | C | X | C | C | C | | | | | | |

C = High Complement; c = Low Complement.

SUMMATION

| | Females | Males | Offspring |
|---|---|---|---|
| Group I | c 5 | c 5 | c 9 |
| | C 20 | c 20 | c 11<br>C 25 |
| Group II | C 12 | C 12 | C 20<br>c 1 |
| | c 2 | C 2 | c 1<br>C 1 |

The 5 complement-deficient females, 1-5, in group I, mated with complement-deficient males, produced 9 offspring,[1] all of which proved to be complement-deficient as were their parents. The 20 high complement females, 6-25, in group I, crossed with the low complement males, dropped 36 offspring, 25 of which showed the usual amount of complement as did their dams, while the remaining 11 inherited the deficiency which characterized their sires. The two offspring of low complement female 38 in group 2 represented the reciprocal cross and, likewise, manifested the contrasted complement characters possessed by their parents. Nos. 25 (high × low) and 39 (low × high) did not breed. From the 12 high complement females, 26-37, in group II, mated with their kind, 21 offspring were secured, 20 of which were like their parents with respect to complement, while one, the offspring of female 30, displayed the recessive character in striking contrast to its parents and the other progeny of like parentage.

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[1] The offspring were bled when only a few days old, indeed sometimes when only a few hours old, their blood serum being tested for complement in amounts up to and including 0.3 c. c. whole serum. Sera, 0.04 c. c. of which gave no evidence of complement, were regarded as complement-deficient and all animals furnishing such serum were bled again if they lived to sufficient age to provide serum for a 1 c. c. test as well. The blood was drawn directly from the heart while the animal was under ether anesthesia.

Owing to lack of information as to the complement character of the parents of the foundation animals, the preponderance of high complement individuals could not be accepted as proof of the dominance of that character expression, but a similar preponderance displayed by the progeny of cross-bred animals left no room for doubt as to the direction of dominance. This important disclosure seemed to enable a fairly safe interpretation of the genetic constitution of a considerable proportion of the filial population as well as that of all the parents of complement-deficient offspring.

The obvious direction of dominance necessitated the assumption that all the low complement individuals were homozygous for that complement expression and, therefore, would always breed true with respect to it when mated with their kind. The offspring of females 1-5 seemed to fulfil this requirement, although the number was too small to be taken very seriously *per se*.

Since the high complement animals employed in these preliminary trials had been produced as the result of mixed mating and since complement-deficient individuals had participated in such chance mating, it seemed safe to assume that two distinct genotypes were in hand, one homozygous and the other heterozygous for the full complement expression. This assumption seems amply confirmed by the character of the progeny of cross-mating, for if all of the high complement parents had been homozygous for the character there should have been no complement-deficient young, and had they all been heterozygous dominants the high and low complement offspring should have been approximately equal. The 26 high to 13 low complement offspring actually obtained from such mating indicated that approximately one-third of the high complement parents were homozygous for their complement expression while the remaining two-thirds were heterozygous for the same. Nine of the high complement females disclosed their heterozygous nature by producing one or more low complement offspring, but the other hybrid mothers could not be distinguished from the pure dominants until further subjected to the hybrid test, to wit, mating with recessives.

Even more uncertainty as to genotypic constitution existed in respect to females 26-37 as well as the males with which they were mated, for three combinations for mating were possible, namely, homozygous with homozygous, homozygous with heterozygous, and heterozygous with heterozygous. All but one of the 21 resulting offspring presented the dominant complement character like the parents, but as in the case of the parents it seemed reasonable to expect that a considerable proportion, perhaps two-thirds, would not breed true to their complement phenotype.

Both parents of the one low complement offspring must have been heterozygous in respect to their high complement character, for with neither of the other two possible mating combinations should a low complement offspring have been possible. In the case of heterozygous parentage, however, one-third of the offspring should inherit the deficiency as the result of segregation of the complement factor in gametogenesis. The case in question not only disclosed the genotypical nature of female 30, but it also furnished further proof of the dominance of the full-complement expression which, in itself, seemed to justify the mating of so many high complement females with their genotypically uncertain kind.

As already has been stated, the genetic constitution of the 20 full-complement progeny of full-complement parentage (26-37 in group II) was not clear until it was determined by further selective mating. However, the genetic constitution of the remaining 49 progeny of females 1-24 and 38 seemed easy to fix, for the reason that they either proved complement-deficient on applying the complement-fixation test or that they were the offspring of a complement-deficient parent or parents, which of itself seemed to guarantee their identity.

All of the females used in the preliminary breeding trial, together with the daughters they produced, were next mated with low complement males. The largest possible number of recessive offspring was then secured with which to prosecute the experimental breeding and, furthermore, all of those displaying the dominant character should prove heterozygous for the same. Moreover, the use of low complement males with the mixed class of dominant females served gradually to identify those individuals possessing but a single dose of each complement factor, for such sooner or later disclosed their genotypical nature by dropping one or more low complement offspring. The low complement females continued to breed true to their phenotype and the heterozygous dominants produced nearly equal numbers of low and high complement offspring in accordance with Mendelian expectations. At times the exact 50-50 ratio obtained but more frequently the numbers of either one phenotype or the other were slightly in excess.

These satisfactory results continued without serious interruption until the spring of 1916, when the breeding stock became infected with *B. suisepticus,* from which a very large proportion, over 700 animals, eventually died. The disease thus caused assumed a chronic form in many of the full-complement animals, most of which developed more or less extensive lesions in the liver, spleen and peritoneum. A large part of the low complement animals, however, died within from a few hours to one or two days, without developing the gray necrotic foci so frequently found in those possessing more complement. Postmortem examination of these animals usually revealed accumulations of fluid in the large body cavities and dark colored serous membranes.

Previous to the outbreak of this disease the proportion of high to low complement offspring in connection with the hybrid-recessive cross had constantly approximated the expected ratio, but during the progress of the disease a preponderance of high complement progeny developed. The size of the discrepancy, which at no time exceeded the probable error, did not cause much concern, but its development in connection with the disease and its persistance could not be regarded as mere coincidence. On the contrary, the discrepancy seemed to be due directly to the different degrees of resistance to the disease offered by the unborn high and low complement offspring of the infected high complement females while suffering from a chronic form of the disease. Some females, presumably carrying only low complement offspring, lost them prematurely, while others, presumedly bearing only high complement offspring, were able to carry their young to sufficient age for bleeding. (In this connection see pages 21-23.)

The September 1, 1916 record of offspring from this cross showed 320 complement-deficient animals and 353 possessing full measure of complement. The latter group was consistently the larger during the remaining three years of breeding, although the offspring produced during the latter period approximated the expected 50-50 ratio, in this respect being comparable to the result obtained during the two years preceding the suipestifer infection. While the total number of high complement offspring, including those produced prior to and during the course of the disease, remained constantly in excess during the last three years of breeding there were actually six more low than high complement animals produced during this latter period.

The lethel nature of the complement-deficient character was evidenced at an early stage of the breeding by the greater mortality among the low complement animals. Consequently bleeding when only a few days old was resorted to, in order to enable an early complement test. Enough blood was readily and safely secured at that early age. While the phenotypical ratios obtained in both the hybrid-recessive and the hybrid-hybrid matings under favorable conditions have been satisfactory, at no time during the six years' breeding has it been possible to raise and maintain as large a proportion of the low complement as of the high complement animals.

The breeding experiment was seriously embarrassed in the spring of 1917 by the loss of over 800 of the breeding animals, including most of the low complement females, because of faulty feeding. Up to that time the interbreeding of hybrids, the most salient feature of Mendelian studies, had not been tried. To enable the production of hybrids for this important mating, about 200 strong, mature females were purchased and used for hybridizing with low complement males. From this cross 709 offspring were secured, not one of which showed the low complement expression which characterized their sires. The average complement titer of both the offspring and their dams was almost exactly 0.06 c. c. of 20 percent solution of serum, while the sera of none of the sires used produced hemolysis in quantities up to 1 c. c. of clear serum. This result seemed to guarantee the homozygous nature of the dams and, likewise, the suitability of their offspring for the hybrid breeding test.

By interbreeding the hybrid progeny of this cross a second filial generation ($F_2$) comprising 1,209 animals was secured. Factor segregation quite typical of the $F_2$ generation of monohybrid crosses was shown throughout the employment of this mating by a close approximation to the expected 3 to 1 ratio. By reference to table II, which shows the total number of high and low complement offspring obtained in each of the matings employed, it may be seen that 907 mixed dominants and 302 recessives were secured by the hybrid-hybrid mating up to September 1, 1919, which represents a ratio of 3.0008 to 0.9992, the closest possible approximation to the 3 to 1 ratio.

A total of 2,046 offspring was secured for the complement test by breeding entirely within the complement-deficient phenotype. Not one of these offspring afforded serum capable of causing even a trace

TABLE II. COMPLEMENT CHARACTER OF OFFSPRING SECURED FROM PEDIGREE BREEDING

| Parents | | Offspring | | | | | |
|---|---|---|---|---|---|---|---|
| Matings | | CC<br>+ | CC — Cc<br>+ +<br>+ | Cc<br>+ | cc<br>— | Totals | Ratios |
| CC | CC | 355 | | | | 355 | |
| CC | Cc | | 114 | | | 114 | |
| CC | cc | | | 709 | | 709 | |
| Cc | Cc | | 907 | | 302 | 1209 | 3.0008 : 0.9992 |
| Cc | cc | | | 711 | 690 | 1401 | 1.015 : 0.985 |
| cc | cc | | | | 2046 | 2046 | |
| | | 355 | 1021 | 1420 | 3038 | 5834 | |

CC = Homozygous dominant; Cc = Heterozygous dominant; cc = Recessive; + = High complement; — = Complement-deficient.

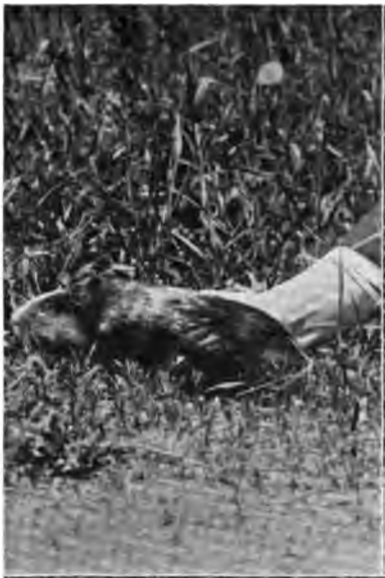
By allowing C to represent the high complement factor and c that responsible for deficiency of the character, the three possible factor combinations can be expressed by CC, Cc and cc, respectively. The first (CC) is used to represent the genetic constitution of a homozygous dominant, the second (Cc) that of a heterozygous dominant, while the third (cc) is used to express the recessive genotype.

As a necessary result of chromosome reduction, which seems to be the most salient feature of gametogenesis, these combinations are always broken and, as a result, the individual factors are left free in their respective gametes to recombine during fertilization with one or the other of the contrasted factors (C or c) from the opposite sex. Obviously the genotypical constitution of the resulting offspring will depend upon the kind of complement factor (C or c) available for such recombination.

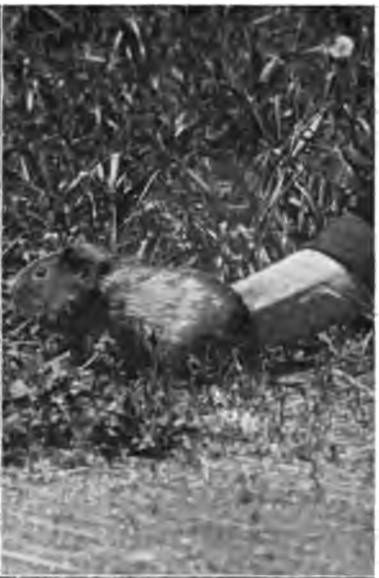
Homozygous dominants of both sexes provide only C factors, consequently they always breed true. Likewise recessive (cc) individuals, which are also homozygous, breed true since they can produce none but c gametes. When, however, CC and cc individuals are crossed each contributes its particular kind of gamete and none other, and, consequently, the only combination possible is Cc; but since C is dominant the resulting hybrid offspring always displays the full measure of complement. Such hybrid individuals produce, as the result of chromosome reduction, equal numbers of C and c gametes. When mated with their kind for the production of a $F_2$ generation the chances are equal that C will combine with C or with c and, likewise, that c will combine with C or c; consequently CC and cc offspring occur in equal numbers, but the Cc individuals will, on the average, be equal in number to the sum of the other two.

While the genotypical ratio thus obtained is 1CC : 2Cc : 1cc, owing to the dominance of the C factor the phenotypical ratio presented is three high complement individuals (1CC + 2Cc) to one deficient for the character.

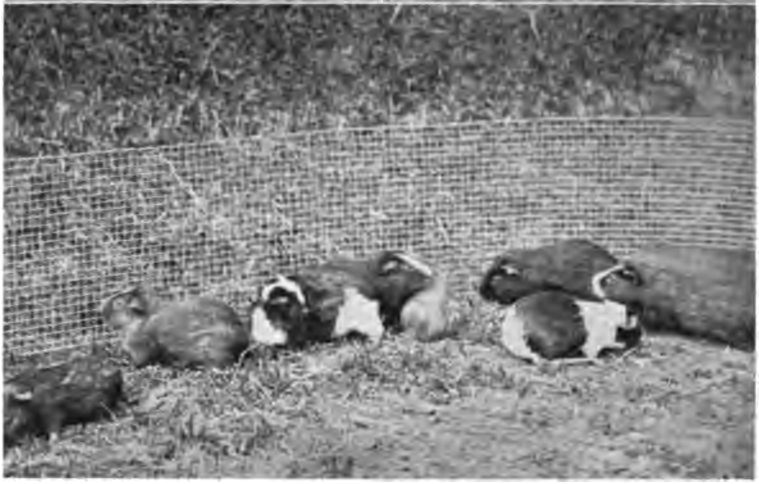
When Cc and cc individuals are crossed, equal numbers of the Cc and cc offspring are produced because the c gametes of the recessive have an equal chance of combining with C or with c gametes contributed by the hybrid.



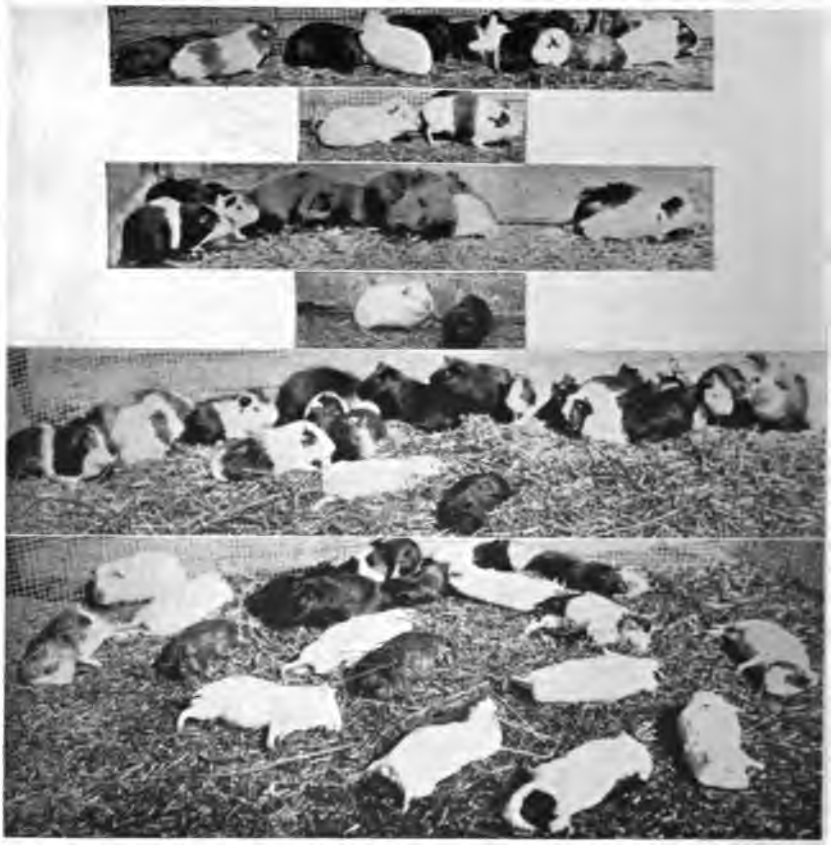
Complement-deficient four weeks after injection of complement-positive serum. (See page 23.)



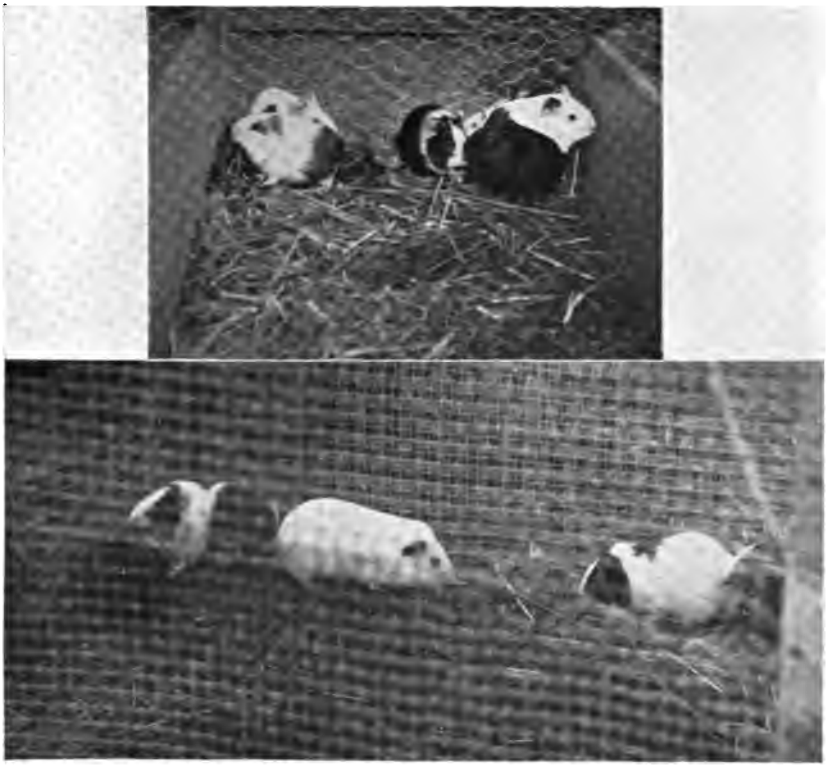
Complement-deficient three weeks after injection of defibrinated blood from complement-positive. (See page 24.)



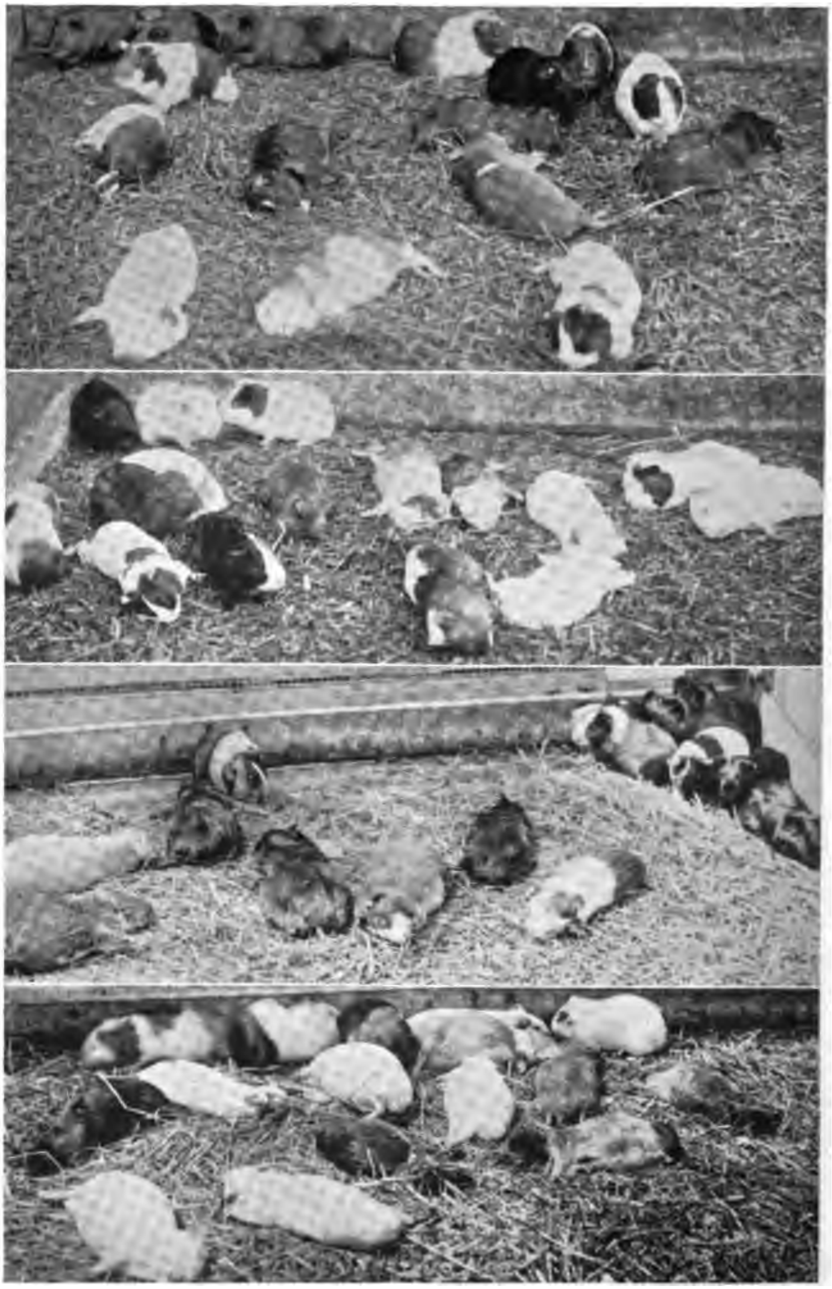
Complement-positives fed cabbage for 67 days. (See page 15.)



From top to bottom: Survivors (June 24) of 14 positives, inoculated June 10;
Survivors (June 24) of 14 deficients, inoculated June 10;
Survivors (June 24) of 20 positives, inoculated June 11;
(See pages 21-23.) Survivors (June 24) of 20 deficients, inoculated June 11;
Twenty positives, inoculated June 11, photographed June 14;
Twenty deficients, inoculated June 11, photographed June 14.



Above, complement-positives; below, complement-deficients.



From top to bottom: 16 positives, inoculated June 22, photographed June 24;
16 deficients, inoculated June 22, photographed June 24;
16 positives, inoculated July 4, photographed July 6;
16 deficients, inoculated July 4, photographed July 6.

(See pages 21-23.)

of hemolysis in 0.04 c. c. of their whole serum and all showed more or less lack of complement in 0.3 c. c. whole serum when titrated with a horse hemolytic system. The unfailing certainty with which this new strain of cavies transmits absence of complement in amounts of serum ordinarily used in complement titrations seems to prove beyond a shadow of doubt the homozygosity of its genetic constitution.

The complement titre of the serum furnished by the different complement-deficient animals produced from the matings employed varied from less than 0.3 c. c. to 2 c. c. Prior to 1915, 0.3 c. c. was the largest amount of serum regularly employed in connection with the tests for complement, but in 1915 a 1 c. c. tube was added and amounts up to 2 c. c. have been used in some cases, although 0.3 c. c. was the largest amount employed in the first test which was invariably made when the animal was but a few days old. The serum obtained from about 5 percent of the animals subjected to this more rigid test in 1915-16 showed no complement activity in amounts up to and including 1 c. c. whole serum; that furnished by about 12 percent caused partial hemolysis in the 1 c. c. tube; and that supplied by 18 percent produced partial hemolysis in the 0.3 c. c. tube.

This wide range of variation suggested the possible involvement of more than one hereditary factor, yet on the other hand the ratio of high to low complement obtained seemed to indicate that only a single factor was concerned in its production. In order to settle this point, if possible, all of the available complement-deficient females were segregated into four groups according to the apparent extent of deficiency of complement in their serum. Matings within each group were made with males of their own kind respecting the extent of complement deficiency. Group 1 contained all those whose serum gave a complement titre of 1 c. c. and over; group 2 contained those 1 c. c. of whose serum caused partial hemolysis; group 3 contained all those females furnishing 0.3 c. c. complement-negative serum, 1 c. c. of which produced complete hemolysis; and group 4 contained those 0.3 c. c. of whose serum produced partial hemolysis. Two generations of offspring, secured while these groupings and selective matings were maintained, failed to show any tendency whatsoever to transmit the complement titre of the parents. In fact, the largest proportion of 1 c. c. complement-deficient offspring was obtained in group 4.

Notwithstanding the negative result of this trial, which seemed to eliminate the possibility of there being more than one factor involved in the whole range of variation, the exclusive use of 1 c. c. complement-negative sires throughout the remainder of the breeding experiment seemed to produce a profound effect in the direction of increasing the average measure of complement deficiency. During this latter period of breeding over 30 percent of the low complement offspring secured furnished 1 c. c. complement-deficient serum as compared with 5 percent obtained during 1915-16 and less than 10 percent of the sera furnished by the balance produced any hemolysis in the 0.3 c. c. tube.

Table III sets forth the results of a rough titration of the sera of the breeding females used in 1916; table IV of the sera of the males used in 1916; and table V the results secured in sera titration, 50 animals being selected at random in 1919.

### TABLE III

**Complement titrations of the sera of breeding females used in 1916**
**117 animals**

0.04 c. c. Uniformly —
0.3 c. c. Uniformly —
1 c. c. As stated below

| | | |
|---|---|---|
| ++ | Nos. 1-3, 5-7, 9-14, 16-21, 24-32, 34, 35, 37-39, 41-47, 49, 51-53, 55-57, 59-63, 65-71, 73-76, 78-83, 85-102, 104-111, 113, 114, 116, 117 | Total 98 |
| + | Nos. 4, 15, 23, 36, 40, 48, 50, 54, 64, 77, 112, 115 | Total 12 |
| — | Nos. 8, 22, 33, 58, 72, 84, 103 | Total 7 |

### TABLE IV

**Complement titrations of the sera of sires used in 1916**
**16 animals**

0.04 c. c. Uniformly —
0.3 c. c. Uniformly —
1 c. c. As stated below

| | | |
|---|---|---|
| ++ | Nos. 2, 7, 13, 15 | Total 4 |
| + | Nos. 5, 10 | Total 2 |
| — | Nos. 1, 3, 4, 6, 8, 9, 11, 12, 14, 16 | Total 10 |

### TABLE V

**Complement titrations of the sera of recessive offspring produced in 1919**
**50 animals**

0.04 c. c. Uniformly —
0.3 c. c. Nos. 11 and 30 +; remainder uniformly —
1 c. c. As stated below

| | | |
|---|---|---|
| ++ | Nos. 11, 17, 18, 24, 30, 39, 50 | Total 7 |
| +— | Nos. 3, 4, 7, 9, 10, 12, 15, 22, 25-27, 34, 35, 37, 38, 40, 41, 44, 46, 47 | |
| — | Nos. 1, 2, 6, 8, 13, 14, 16, 19-21, 23, 28, 29, 31-33, 36, 42, 43, 45, 48, 49 | Total 22 |
| —— | No. 5 | Total 1 |

| | |
|---|---|
| — | No hemolysis in 1 c. c. clear serum |
| + | Partial hemolysis in 1 c. c. clear serum |
| ++ | Complete hemolysis in 1 c. c. clear serum |
| +— | Trace of hemolysis in 1 c. c. clear serum |

It is interesting to note that Schlesinger,[1] in discussing discrepancies in Wassermann determinations, states that he has "found that it is the complement that varies"; that "the complement value of the guinea pig serum calls for attention"; that "in guinea pigs fed exclusively on cabbage leaves, the serum has little or no complement value (whereas) when oats are fed the complement value is raised materially sometimes to the extent of four or five times." The chances are that Schlesinger actually had complement-deficient pigs and did not know it. His contention that diet was responsible for the variations in titre is abundantly disproved by the following experience at this Station.

Ten complement-positive pigs with closely comparable complement titres were selected at random and during two weeks gradually changed from a cut hay, sliced vegetable (carrot, beet, cabbage, turnip) and grain (oats and cracked corn) diet to an exclusive cabbage diet on which they were held for 67 days. They were then allowed to eat all the oats they would consume for 30 days. The titrations at the beginning of the trial, at the close of the cabbage feeding period and at the close of the oat feeding period were essentially unchanged. This observation was confirmed by the results secured at this Station with a great variety of feeds given to many hundreds of pigs during several years. In no case whatsoever was any evidence secured to indicate that changes in feeding affected the complement titre.

In this connection it may be noted that neither castration nor pregnancy affected the complement contents of the serum of either complement-positive or complement-deficient pigs, but that frequent and copious bleeding tended to reduce the titre from one-third to one-half.

In the course of these trials many different glands, divers organs, viscera, etc., were macerated and the extracts titrated with a view of determining the presence or absence of complement. It was never discovered outside of the blood serum.

## NATURE OF THE HEREDITARY FACTOR

While the measure of deficiency of complement found in the low complement cavies seems to fulfill the requirements of a simple Mendelian character conditioned upon a single hereditary factor, it seems possible by invoking the aid of the factor hypothesis also to explain the presence of some complement in their serum evidenced when sufficiently large amounts of the latter are used for the complement test and especially when the more sensitive human haemolytic system is employed. In fact, the factor hypothesis offers two different explanations:

---

[1] Med. Red., Jan. 9, 1915, pp. 61 ff.

1. By assuming that the deficiency is due to the loss, by mutation, of an intensifying factor, the function of which is to modify the complement factor in the direction of increased production of complement.

2. By assuming that the full measure of complement is conditioned upon the combined action of two identical hereditary factors and that the mutation involved the loss of one of these duplicate genes without disturbing the other.

It would be necessary to find a complement-deficient animal, that is to say one in whose serum no evidence of complement could be demonstrated with any haemolytic system or by using any amount of serum, to enable a determination as to which of these factor combinations obtained. If on mating such an individual with a homozygous high complement animal, high complement hybrids should be obtained, and if on mating the latter together a mixed progeny comprising high, low and deficient complements in the proportion of 11-4-1 should result, then it would appear certain that two identical complement factors conditioned the full measure of complement. (Second case cited on page 17.)

On the other hand, if conditioned by a complement and an intensifying factor, the result of mating the extremes together would depend upon whether the needed complement deficient, when found, had or did not have the intensifying factor, although its phenotypical expression would be the same in both cases, since the absence of complement factor and, therefore, complement, would render the intensifying factor functionally helpless. These results and the method of determining the same are illustrated on the opposite page, by referring to which it may be seen that in case the C deficient mutant had possessed the intensifying factor, the $F_2$ generation of the full complement deficient cross should give high complement and complement-deficient offspring in the ratio of 3 : 1. (Third case cited on page 17.)

If, however, the complement-deficient mutant did not possess either the intensifying or the complement factor, then the $F_2$ generation should comprise three phenotypes, namely, high complement, low complement and no complement in the ratio of 9-3-4. Since the latter case would involve a double mutation, it would be far less likely to occur than the loss of the complement factor and retention of the supplementary factor. (First case cited on page 17.)

FIRST CASE

| | C I | C i | c I | c i | | | |
|---|---|---|---|---|---|---|---|
| C I | C I<br>C I | C i<br>C I | c I<br>C I | c i<br>C I | = 4 high | | |
| C i | C I<br>C i | C i<br>C i | c I<br>C i | c i<br>C i | = 2 high | 2 low | |
| c I | C I<br>c I | C i<br>c I | c I<br>c I | c i<br>c I | = 2 high | | 2 deficient |
| c i | C I<br>c i | C i<br>c i | c I<br>c i | c i<br>c i | = 1 high | 1 low | 2 deficient |
| | | | | | 9 high | 3 low | 4 deficient |

SECOND CASE

| | C C | C c | c C | c c | | | |
|---|---|---|---|---|---|---|---|
| C C | C C<br>C C | C c<br>C C | c C<br>C C | c c<br>C C | = 4 high | | |
| C c | C C<br>C c | C c<br>C c | c C<br>C c | c c<br>C c | = 3 high | 1 low | |
| c C | C C<br>c C | C c<br>c C | c C<br>c C | c c<br>c C | = 3 high | 1 low | |
| c c | C C<br>c c | C c<br>c c | c C<br>c c | c c<br>c c | = 1 high | 2 low | 1 deficient |
| | | | | | 11 high | 4 low | 1 deficient |

THIRD CASE

| | C I | c I | | |
|---|---|---|---|---|
| C I | C I<br>C I | c I<br>C I | = 2 high | |
| c I | C I<br>c I | c I<br>c I | = 1 high | 1 deficient |
| | | | 3 high | 1 deficient |

It seems fair to say that the genetic studies, the results of which are reported on the preceding pages, indicate:

1. That complement is not a universal blood factor.
2. That there are guinea pigs in whose blood stream no trace whatsoever of complement was demonstrable in the amounts of serum normally used for titration purposes.
3. That in view of this fact it is unsafe to assume the existence of complement in any laboratory animal whatsoever, but that, on the contrary, each such animal should be tested for its complement content.

4. That the character known as complement is apparently controllable by selective mating in connection with hereditary variation.

5. That entire conformity to Mendel's law was displayed in respect to the complement character of the strains of guinea pigs used during these trials.

6. That complement is unaffected by dietary change, castration or pregnancy.

## THE RELATION OF COMPLEMENT TO OPSONINS

There are certain substances in the blood, called opsonins (Greek *opςoπειπ*, to prepare a meal), the apparent function of which is so to act upon bacteria or other foreign organic material as to prepare them for more ready ingestion by the white blood corpuscles or polymorphonuclear nutrophil leukocytes. Their source is unknown. Two kinds are recognized, normal and acquired.

The opsonic index (O. I.) represents the ratio of the number of bacteria ingested by a given number of such leukocytes in the presence of a given patient's serum (X's L. I.) to the number ingested by the same number of leukocytes in the presence of normal serum (C. L. I.). Stated in mathematical terms, with X the patient and C the control, we have: $\frac{\text{X (L I)}}{\text{C (L I)}} = \text{O I.}$

The determination of the opsonic index is somewhat time-consuming, necessitates much care and exactitude, calls for special training, involves a somewhat complicated technic and is usually confined to the research laboratory. The information it supplies has significance to the clinical diagnostician and the practitioner in respect to immunity and disease resistance.

Several months of rigid preparation in acquiring the technic of opsonic index determination preceded the initiation of the work herein reported, following which 27 such tests were made, the complement-positive sera being used as norms, the complement-deficient sera as abnorms. At the time of each index determination control titrations of the two serums were made, the horse hemolytic system being used, with strictly uniform results each time, namely, no hemolysis with 0.04, 0.3 or 1 c. c. of serum in the complement-deficient; no hemolysis with 0.02, partial hemolysis with 0.04 and complete hemolysis with 0.06 to 0.1 c. c. of serum in the complement-positive serums. The counts were made during February, March and April, 1919. Two counts were checked by Dr. E. H. Buttles, Professor of Pathology and Bacteriology in the College of Medicine, and one by the Station Plant Pathologist, with results essentially identical with those obtained by the usual operator. In most cases, in order that no personal bias might enter into the determination, the worker had an associate so manipulate the tubes that he himself did not know which he was working with at any given time.

The final results follow, indicating in each case the number of bacteria ingested by 100 or by 50 leukocytes.

| | | Number ingested | Minimum and maximum numbers ingested | Number ingested | Minimum and maximum numbers ingested | Index |
|---|---|---|---|---|---|---|
| No. 1 | | 240 | 0-8 | 743 | 1-17 | .323 |
| “ 2 | | 369 | 0-18 | 877 | 1-25 | .4207 |
| “ 3 | | 463 | 0-12 | 856 | 0-18 | .5408 |
| “ 4 | (50) | 180 | 0-9 | 279 | 0-12 | .6451 |
| “ 5 | | 361 | 0-32 | 784 | 0-33 | .4604 |
| “ 6* | (50) | 229 | 0-34 | 387 | 0-41 | .5917 |
| “ 7 | (50) | 164 | 0-25 | 402 | 0-25 | .4079 |
| “ 8 | (50) | 354 | 0-50 | 653 | 0-50 | .5421 |
| “ 9 | | 447 | 0-40 | 902 | 0-43 | .4955 |
| “ 10 | | 790 | 0-56 | 1155 | 0-60 | .6839 |
| “ 11† | (50) | 439 | 0-50 | 587 | 0-60 | .7461 |
| “ 12 | | 350 | 0-32 | 735 | 0-50 | .4761 |
| “ 13 | | 721 | 0-45 | 1082 | 0-48 | .6663 |
| “ 14 | | 298 | 0-31 | 635 | 0-37 | .4692 |
| “ 15 | | 532 | 0-31 | 785 | 0-33 | .6777 |
| “ 16 | | 374 | 0-40 | 953 | 0-50 | .3925 |
| “ 17 | | 215 | 0-10 | 571 | 0-31 | .3765 |
| “ 18‡ | (50) | 97 | 0-11 | 288 | 0-15 | .3368 |
| “ 19 | | 212 | 0-16 | 426 | 0-22 | .4976 |
| “ 20 | | 155 | 0-21 | 592 | 0-20 | .2618 |
| “ 21 | | 441 | 0-20 | 704 | 0-38 | .6264 |
| “ 22 | | 434 | 0-34 | 628 | 0-40 | .6910 |
| “ 23 | | 177 | 0-9 | 607 | 0-25 | .2915 |
| “ 24 | | 165 | 0-16 | 739 | 0-44 | .2232 |
| “ 25 | | 272 | 0-12 | 547 | 0-33 | .4973 |
| “ 26 | | 360 | 0-33 | 553 | 0-43 | .6509 |
| “ 27 | | 207 | 0-10 | 736 | 0-40 | .2813 |
| Totals | | 9046 | | 18206 | | |
| Averages | | 335 | | 674 | | .4969 |

It will be observed that in every case the leukocytes in the presence of the complement-positive serum displayed a more active phagocytosis than did those working in the presence of the complement-deficient serum. There was no exception in any one of the 27 comparative determinations. The index figure fluctuated, being sometimes relatively high and sometimes relatively low, extremes being .2813 and .7461, but the results were always in one direction, the average being .4969. The opsonic index of the sera of the complement-deficient pigs was one-half that of the sera of the complement-positive pigs. Minor variations were made in the technic from time to time, as suggested by experience, always with a view of giving the "under dog," so to speak, every possible chance, but without changing the trend of the results. In view of the decided pathogenicity of *B. typhosis* and of *Staphylococcus aureus,* it would seem that this line of experimentation served to confirm the results secured with direct infection.

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*Check on No. 5 by Dr. Buttles; †Check on No. 10 by Dr. Buttles; ‡Check on No. 17 by Station Plant Pathologist.

The opsonic determinations just cited, using the serum of immunized animals, showed a 50 percent deficiency of natural opsonins. This seemed to explain the relative lack of resistance to initial exposure to infection exhibited by the low complement animals. It is, of course, well understood that the bactericidal action of complement does not become available until the sensitizing antibodies have been developed in the blood.

It seemed desirable at this point to attempt to determine whether there might not be developed, through immunization, a supply of acquired opsonins. Consequently, suspensions of Staphylococcus aureus were thrown into the blood streams of 30 complement-positive and 30 complement-deficient pigs at weekly intervals for a month. There then were introduced living cultures of the same organism. Seventeen different comparative counts were made at varying dates, shortly following the last injection with results as follows:

| | Complement-deficient | | Complement-positive | | |
|---|---|---|---|---|---|
| | Number ingested | Minimum and maximum numbers ingested | Number ingested | Minimum and maximum numbers ingested | Index |
| No. 1 | 552 | 0-21 | 541 | 0-35 | 1.02 |
| " 2 | 956 | 0-28 | 726 | 0-25 | 1.316 |
| " 3 | 458 | 0-26 | 493 | 0-25 | 0.929 |
| " 4 | 490 | 0-37 | 466 | 0-35 | 1.051 |
| " 5 | 698 | 0-35 | 698 | 0-40 | 1. |
| " 6 | 538 | 0-42 | 507 | 0-28 | 1.061 |
| " 7 | 687 | 0-44 | 949 | 0-40 | 0.724 |
| " 8 | 933 | 0-32 | 849 | 0-25 | 1.098 |
| " 9 | 1130 | 0-30 | 1114 | 0-36 | 1.014 |
| " 10 | 895 | 0-39 | 901 | 0-40 | 0.993 |
| " 11 | 979 | 0-40 | 991 | 0-54 | 0.987 |
| " 12 | 798 | 0-30 | 848 | 0-26 | 0.941 |
| " 13 | 445 | 0-34 | 383 | 0-35 | 1.162 |
| " 14 | 448 | 0-39 | 499 | 0-30 | 0.897 |
| " 15 | 601 | 0-22 | 525 | 0-40 | 1.144 |
| " 16 | 370 | 0-51 | 255 | 0-40 | 1.45 |
| " 17 | 448 | 0.40 | 478 | 0-34 | 0.937 |
| | 672 | | 660 | | 1.043 |
| | | ÷ | | | 1.019 |

The results of this trial seem to indicate that immunization of the complement-deficient animals caused the development of acquired opsonins, capable of bringing the phagocytic index up to the level of that of the complement-positive pigs, in so far as the particular organism used is concerned. The figures were practically identical. Complement was not increased; hence apparently bacteriolytic immunity must have been limited by the deficiency of complement, even though the organisms were sensitized by antibodies in preparation for complement action.

## THE SUSCEPTIBILITY TO DISEASE OF COMPLEMENT-DEFICIENT PIGS

The striking deficiency in complement found in the Middlesex strain of guinea pigs naturally suggested the study of the relative disease resistance offered by that strain as compared with that of complement-normal pigs. The following trials are typical of several carried on during the course of the study.

1. In 1917-18 a considerable infection occurred in the breeding pens as is set forth on page 10. Two organisms, a bacillus and a coccus, isolated from the lungs of diseased pigs, seemed likely to be at fault. The former was found, following inoculation, to be highly pathogenic, killing in some cases within 5 hours of injection. One hundred percent lethality within 48 hours occurred when 10 pigs were injected with the bacillus, whereas only 40 percent followed injection with the coccus. The morphological, cultural and bio-chemical characteristics of the bacillus were determined. It was found to belong to the colon typhoid group. No known organism was found in Chester's manual with which it exactly corresponds.

The next month 40 pigs were inoculated, 20 of each group, *i. e.*, complement-deficient and complement-positive, 10 of each receiving 1/5 slope each of the killed bacilli and 10 of each 1/5 slope each of the killed cocci, the inoculations being intraperitoneal. Three more and increasing doses were given each pig at weekly intervals, the last in each case representing a 1/2 agar culture slope. One week after the last dosage—four weeks after the initial treatment—each pig was bled and its serum tested for bacteriolytic antibodies, each antigen, for bacillus and coccus, having been previously tested and standardized. Five tubes were used for each serum, the amounts used being 0.01, 0.03, 0.05 and 0.1 c. c. of inactivated (56°, 30 min.) serum. The fifth tube contained all the necessary factors except the antigen. The serum of every pig, whether complement-deficient or complement-positive, showed the presence of bacteriolytic antibodies in 0.01 c. c.

Clearly the deficiency of complement in nowise inhibited the production of antibodies, the serviceability of which theoretically is dependant upon the presence of complement.

Immediately thereafter agglutination tests were made with the serum of all these 40 pigs. The results were clear with the bacillus, decided reactions being secured in dilutions up to 1 to 1,000. With the coccus, however, no reaction was secured in greater dilution than 1 to 50. Obviously the lack of complement did not interfere with the production of agglutinating antibodies.

The next day the 40 pigs were inoculated each with a small dose (1/10 of a 24-hour agar slant) of the living organisms. One complement-positive pig inoculated with the bacillus died. Two weeks later the 39 were inoculated with ½ slope of living bacilli and ⅗ slope of living cocci. Three complement-deficient and four complement-positive pigs died. This result was abundantly confirmed by further trials. Clearly complement-deficiency did not interfere with immunity acquired through systematic immunization.

Finally, these pigs were bled and their sera titrated for complement. No hemolysis whatsoever occurred in 1 c. c. of any serum derived from the complement-deficient pigs. The sera of all the complement-positive pigs in every respect proved normal, hemolysis occurring readily.

Apparently complement is not increased during the period of artificial immunization, and pigs deficient therein can not make good that deficiency by means of systematic immunization.

2. Twenty-eight pigs, half of them complement-deficient and half complement-positive, were inoculated each with a 1/15, 36-hour slope of living *B. cholerae suis*. Within 48 hours, 12 of the former lot and two of the latter were dead. At intervals, 40, 32, 32 and 68 others were similarly treated. The results appear in the subjoined table, the deaths all occurring within 48 hours. The plates opposite pages 16 and 17 are illustrative of these trials.

| | Complement-deficient pigs | | | Complement-positive pigs | | |
|---|---|---|---|---|---|---|
| Date | Inoculated number | Deaths number | Deaths % | Inoculated number | Deaths number | Deaths % |
| June 10 | 14 | 12 | 86 | 14 | 2 | 14 |
| " 11 | 20 | 14 | 70 | 20 | 2 | 10 |
| " 22 | 16 | 10 | 63 | 16 | 3 | 19 |
| July 4 | 16 | 11 | 69 | 16 | 2 | 13 |
| Aug. 22 | 34 | 30 | 88 | 34 | 11 | 32 |
| | 100 | 77 | 77 | 100 | 20 | 20 |

It seems reasonable to assume that the deficiency of complement was a factor in the increased death rate.

The complement-deficient animals were veritable cosset pigs. They were weaklings, it was hard to raise them. In order that there might be the greater likelihood of maintaining the strain, it was in part boarded out among people skilled in the business. No less than four different parties had the pigs, were carefully instructed how to handle them, especially in respect to feeding, and every last pig died—whereas their complement-positive mates flourished. On several occasions, a change of feed, feeders or feeding methods in our own hands wrought mischief. And, finally, when they were shipped away for experimental use at Johns Hopkins and at points in Ohio and Oklahoma, although standing transportation well, all eventually died. All of which is corroborative evidence.

## ATTEMPTS ARTIFICIALLY TO INDUCE COMPLEMENT PRODUCTION IN COMPLEMENT-DEFICIENT GUINEA PIGS

Unsuccessful attempts were made by the introduction of fresh active complement from a positive individual into the vascular system of a deficient of the same species with a view of inducing or stimulating its production in the blood stream. The following cases are typical of the studies made along this line:

1. A positive pig (titration relatively high, 0.04) was etherized, bled, the blood centrifuged and 4 c. c. serum secured, which was placed at body temperature in an incubator. A strong complement-deficient pig was similarly bled, the syringe detached, the needle remaining in place, through which the warm sterile complement-positive serum was slowly and cautiously syringed into the throbbing heart. All procedures were carried out with extreme precaution against infection. The pig seemed to be fully recovered the next day. He was bled 50 hours later and repeatedly bled at 3-day intervals for some weeks, but no complement was found in the serum. He was in excellent condition four weeks after treatment.

A positive pig (titration 0.04) was bled freely, the blood thoroughly defibrinated with glass beads, filtered through sterile gauze and the filtrate placed at body temperature in an incubator. A strong complement-deficient pig was similarly bled under full surgical anesthesia, the syringe detached, the needle remaining in place, through which the warm sterile complement-positive defibrinated blood was very slowly and cautiously syringed into the throbbing heart. All procedures were carried out under extreme precautions against infection and normal saline solution used in rinsing all vessels in order to prevent blood cell disintegration.

The pig trembled violently and for several hours displayed evidences of serious disturbance of the vital centers, but, being kept under optimum conditions, apparently recovered within 24 hours. Thirty-five hours after the operation and every other day for some weeks he was bled but no complement whatsoever was found in the serum. He was in excellent condition three weeks after treatment.

It seems quite clear that complement introduced into the blood stream of complement-deficient pigs is quickly and completely dissipated. (See plates opposite pages 16 and 17).

Since this strain of guinea pigs—and quite possibly Schlesinger's (see p. 15)—were very deficient in complement, and since guinea pigs are usually conceded to be among animals *the* great complement producers, it seems fair to infer that this omission may occur, and perhaps not uncommonly, among other species. One may, indeed, conjecture whether or not therein may lie, at least in some measure, the explanation of varying susceptibility to infection as between individuals. In any event, the possession of relatively high complement strains as well as strains deficient in complement enables selective breeding and increases the possibilities of research along lines of immunity and disease resistance.

APRIL, 1923 BULLETIN 231

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# CONCERNING INFECTIOUS ABORTION

BY F. A. RICH

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# BULLETIN 231: CONCERNING INFECTIOUS ABORTION

By F. A. Rich
Former Station Veterinarian

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## I. STUDIES AT THE VERMONT STATION

The Vermont Station began its abortion studies 20 or more years ago. Its resources have always been limited, its buildings and other equipment meagre, its activities circumscribed, the amount of money which could be allotted to this work small. Furthermore, the writer's time and energies have been largely employed in teaching. Interruptions have been frequent and discouragements many. Circumstances have compelled the abandonment of the uncompleted project. Such results as have been secured are summarized herewith.

The causal organism, the abortion bacillus of Bang, was repeatedly isolated from material secured from many herds. It was identified early in the 1900's. It was found in the uterus, uterine contents, fœtus, etc. At no time was evidence secured to indicate that any other organism factored, although no special study of this phase of the subject was attempted.

### METHYLENE BLUE (FOUR HERDS)

Some 10 years ago bulletin 174 was issued, entitled, "Methylene Blue, a Remedy for Infectious Abortion." It was a preliminary, as viewed in the retrospect doubtless a premature, publication. It set forth the results of certain then incomplete and preliminary trials in which methylene blue was used as a remedial agent. It stated:

1. That a 1:4,000 solution destroyed the organism in from four to eight minutes and a 1:6,000 to 1:10,000 solution in from one to three hours.
2. That when fed twice daily in ⅓-½ ounce doses for some weeks, little or no abortion had occurred in four herds in which the disease had been prevalent immediately preceding the inception of the treatment, 38 abortions having taken place within a few months.
3. That 92 cows in these four herds, all reacting to the agglutination test, were thus treated and that at the time of publication, 56 had calved, one had aborted and 35 were still with calf.[1]
4. That no controls were employed, the herd owners not permitting such procedure.

These striking results have not been confirmed by further work either here or elsewhere. Strains of the organism very much more resistant to methylene blue than that with which the writer was working in 1912 have been tested, strains which, according to Hadley, resisted a 1:4,000 solution for three days instead of four minutes. Furthermore, as is set forth on pages 5 to 8, while cows to which methylene blue was fed in trials at this Station carried on subsequent to the issuance of bulletin 174, aborted much less frequently than did control cows not thus treated in the same herds, the proportion of losses was somewhat larger than that indicated in the preliminary bulletin.

---

[1] Five of the 35 subsequently aborted; final percentage of abortion 6.5.

It is not clear just why the initial results were so striking, all but one of the abortions occurring late in the series. It is difficult to believe that immunity was suddenly acquired in four different herds, all of them infected and all of them rife with abortion during the months immediately preceding. Yet the results are as stated—whatever the cause. However, the outbreak of the World War the next summer sent the price of medicinal methylene blue skyrocketing from $2.50 to $80 a pound and its use became prohibitive on that account, even were it effective.

## METHYLENE BLUE; CRESOL (THIRTY-ONE HERDS)

Following the issuance of bulletin 174 attempts were made from 1913 to 1918 to gain access to herds all over the State in which abortion occurred. Tests by the complement fixation method were made in several score of herds, usually with the tacit understanding that treatment would follow; but in a very large share of cases for one reason and another this proved impracticable. When methylene blue was employed its intense coloring effect served to advertise the presence of the malady and to deter buyers. Furthermore, many owners would not permit "controls." "Treat all or none" was their fiat. Indeed, in the 31 herds to which access was allowed and in which the use of controls was permitted, it was as a rule most difficult to secure consent. Frequently a counter-fiat had to be issued—"treat some or none." The writer regrets that no treatment seemed practicable in 20 herds aggregating about 500 cows, in which the preliminary complement fixation tests were made, indicating 50 percent reaction.

Tests were made of some 2,400 animals, almost exactly half of which—1,176 to be exact—became available for use, 431 of them being non-reactors and 745 reactors. Had the others been used, the number of reactors would have approximated 1,000. Several complement fixation tests were made for veterinarians, for county agents and others and a few samples were received in bad condition.

The following table sets forth the results of treatment made in 31 different herds. The results are segregated on the .01, .02, .04 complement fixation test basis—not that that means very much.

The methods of treatment were as follows:

Methylene blue was given when cows were known to be pregnant, but only to a few milkers at one time in order to avoid coloring the milk and other dairy products. About ½ ounce was given daily on silage or grain, for three or four weeks. After an interval of a month or more another three-weeks period of treatment was often given.

METHYLENE BLUE TREATMENT IN HERDS I-XVIII; CRESOL TREATMENT IN HERDS XX TO XXXI; BOTH IN HERD XIX

| Herd number | Date of application of comp. fix. test | Total number in herd | No reaction | Comp. fix. number | | | .01 Control | | .01 Treated | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | .01 | .02 | .04 | Calved | Aborted | Calved | Aborted |
| I | 9-16-13 | 21 | 8 | 7 | 5 | 1 | 2 | 1 | 4 | .. |
| II | 11-18-13 | 38 | 7 | 26 | 2 | 3 | 6 | 5 | 12 | 1 |
| III | 11-24-13 | 30 | 16 | 10 | 2 | 2 | 4 | 2 | 4 | .. |
| IV | 11-29-13 | 87 | 43 | 26 | 10 | 8 | 4 | 3 | 16 | 2 |
| V | 12- 6-13 | 39 | 15 | 13 | 5 | 6 | 3 | 1 | 6 | 1 |
| VI | 12-13-13 | 24 | 3 | 6 | 5 | 10 | .. | 1 | 3 | 2 |
| VII | 2- 5-14 | 27 | 11 | 11 | 2 | 3 | 2 | 1 | 7 | 1 |
| VIII | 2- 5-14 | 3 | 1 | 2 | .. | .. | 1 | .. | 1 | .. |
| IX | 2-12-14 | 33 | 12 | 13 | 2 | 6 | 2 | 3 | 6 | 1 |
| X | 8-11-14 | 11 | 5 | 5 | 1 | .. | .. | .. | 5 | .. |
| XI | 11- 4-14 | 80 | 38 | 14 | 21 | 7 | .. | 2 | 5 | 1 |
| XII | 12-30 and<br>1- 6-15 | 21 | 12 | 3 | 4 | 2 | 1 | .. | 2 | .. |
| XIII | 1-18-15 | 31 | 26 | 4 | .. | 1 | .. | .. | 4 | .. |
| XIV | 3- 4-15 | 76 | 44 | 19 | 10 | 3 | 1 | .. | 5 | 2 |
| XV | 3-13-15 | 65 | 23 | 30 | 10 | 2 | 1 | .. | 3 | 1 |
| XVI | 4-29-15 | 10 | 2 | 6 | 1 | 1 | 1 | 1 | 3 | 1 |
| XVII | 6- 2-15 | 19 | 9 | 2 | 3 | 5 | .. | .. | 2 | .. |
| XVIII | 10-15-15 | 13 | 1 | 8 | 1 | 3 | 1 | .. | 4 | .. |
| | | | | | | | | | 11 | 2 |
| XIX | 11-15-15 | 172 | 54 | 69 | 22 | 27 | 7 | 3 | 10 | 2 |
| XX | 9-29-16 | 32 | 12 | 7 | 5 | 8 | .. | .. | 3 | 2 |
| XXI | 10-31-16 | 56 | 12 | 25 | 17 | 2 | 3 | 1 | 6 | 3 |
| XXII | 11-13-16 | 31 | 15 | 1 | 4 | 11 | .. | .. | 1 | .. |
| XXIII | 11-26-16 | 82 | 9 | 43 | 23 | 7 | 2 | 5 | 19 | 2 |
| XXIV | | 17 | 8 | 7 | 2 | .. | 1 | 1 | 4 | .. |
| XXV | 1-30-17 | 19 | 4 | 5 | 4 | 6 | .. | .. | 1 | 1 |
| XXVI | 5- 6-17 | 22 | 6 | 2 | 1 | 13 | 1 | .. | .. | .. |
| XXVII | 10-29-17 | 20 | 3 | 5 | 10 | 2 | 1 | 1 | 3 | .. |
| XXVIII | 3-11-18 | 41 | 28 | 5 | 4 | 4 | .. | .. | 5 | .. |
| XXIX | 8-22-18 | 22 | .. | 12 | 9 | 1 | .. | 2 | 5 | 1 |
| XXX | 10-10-18 | 12 | 2 | 5 | 5 | .. | 1 | .. | 4 | .. |
| XXXI | 1-15-19 | 22 | 2 | 5 | 10 | 5 | 2 | .. | 2 | .. |
| Totals | | 1,176 | 431 | 396 | 200 | 149 | 47 | 33 | 165 | 26 |
| Percent abortion | | | | | | | | 42 | | 13.6 |

The cresol-molasses mixture was given for about three weeks only to pregnant cows, in amounts varying from 2 to 4 ounces, morning and night on silage or grain. After an interval of one or two months they were frequently subjected to another three-weeks period of treatment. Cows usually object to the mixture at first, but after two or three days take it under protest as evidenced by more or less rooting about the doctored feed and blowing the nose.

Herds I to XVIII, inclusive, were treated with methylene blue; herds XX to XXXI, inclusive, with cresol; herd XIX with both.

METHYLENE BLUE TREATMENT IN HERDS I-XVIII; CRESOL TREATMENT IN HERDS XX TO XXXI; BOTH IN HERD XIX—*concluded*

| .02 Control | | .02 Treated | | .04 Control | | .04 Treated | | Faulty records | Total available animals | Percentage of abortions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Calved | Aborted | Calved | Aborted | Calved | Aborted | Calved | Aborted | | | Controls | Treated |
| .. | 1 | 4 | .. | 1 | .. | .. | .. | .. | 13 | 40 | 0 |
| .. | 1 | .. | 1 | 2 | .. | 1 | .. | 2 | 31 | 43 | 13 |
| .. | .. | 2 | .. | 1 | .. | 1 | .. | .. | 14 | 29 | 0 |
| 2 | 2 | 4 | .. | 2 | 1 | 3 | 1 | 4 | 44 | 43 | 12 |
| 2 | .. | 1 | .. | 3 | .. | 1 | .. | 6 | 24 | *11* | *11* |
| 1 | 2 | 1 | .. | 2 | 1 | 5 | 2 | 1 | 21 | 57 | 31 |
| .. | 1 | 1 | .. | 2 | .. | 1 | .. | .. | 16 | 33 | 10 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | 2 | *0* | *0* |
| .. | 1 | .. | 1 | .. | .. | 5 | 1 | 1 | 21 | 67 | 21 |
| .. | .. | 1 | .. | .. | .. | .. | .. | .. | 6 | *0* | *0* |
| 1 | 2 | 9 | 3 | .. | 1 | 2 | 1 | 15 | 42 | 83 | 24 |
| 2 | .. | 2 | .. | .. | .. | 2 | .. | .. | 9 | *0* | *0* |
| .. | .. | .. | .. | .. | .. | 1 | .. | .. | 5 | *0* | *0* |
| 2 | 1 | 5 | .. | 1 | .. | 1 | .. | 14 | 32 | 20 | 15 |
| 4 | 1 | 4 | .. | .. | .. | 2 | .. | 26 | 42 | 17 | 10 |
| 1 | .. | .. | .. | .. | .. | 1 | .. | .. | 8 | 33 | 20 |
| .. | 1 | 2 | .. | 2 | .. | 3 | .. | .. | 10 | 33 | 0 |
| 1 | .. | .. | .. | .. | 2 | 1 | .. | 3 | 12 | 50 | 0 |
| | | 5 | | | | 5 | 1 | | | | |
| 7 | 4 | 3 | .. | 3 | 1 | 7 | .. | 47 | 117 | 32 | 10 |
| 3 | 1 | .. | 1 | .. | 2 | 2 | 2 | 4 | 20 | *50* | *50* |
| 1 | 5 | 2 | 3 | .. | .. | .. | .. | 20 | 44 | 60 | 43 |
| 1 | .. | 1 | 1 | 1 | 1 | 2 | 4 | 4 | 16 | 50 | 63 |
| 3 | 6 | 8 | .. | .. | .. | .. | 1 | 27 | 73 | 69 | 10 |
| .. | 1 | .. | 1 | .. | .. | .. | .. | 1 | 9 | 67 | 20 |
| 2 | .. | 2 | .. | 1 | 1 | .. | 1 | 6 | 15 | 25 | 40 |
| .. | .. | 1 | .. | 2 | 1 | 7 | .. | 4 | 16 | 25 | 0 |
| 2 | 1 | 6 | .. | .. | 1 | .. | .. | 2 | 17 | 50 | 0 |
| 1 | .. | 3 | .. | 4 | .. | .. | .. | .. | 13 | *0* | *0* |
| 4 | .. | 3 | 1 | 1 | .. | .. | .. | 5 | 22 | 29 | 20 |
| 2 | .. | 2 | .. | .. | .. | .. | .. | 1 | 10 | *0* | *0* |
| 2 | .. | 8 | .. | 2 | .. | 3 | .. | 1 | 20 | *0* | *0* |
| 44 | 31 | 80 | 12 | 30 | 12 | 56 | 14 | 194 | 745 | .. | .. |
| 41.3 | | 13 | | 28.6 | | 20 | | | | 38.8 | 14.7 |

It will be noted:

1. That there were 1,176 cows in 31 herds subjected to the complement fixation test.

2. That 431 of these cows did not react and 745 reacted (⅜ non-reactors, ⅝ reactors).

3. That of the 745 reactors 194, for one reason and another, were "duds." Sales, sterility and "kept farrow" accounted for 9/10 of these failures.

4. That 551 records are available.

5. That of the 551 cows located in 31 herds, 353 were treated and 198 left untreated as controls (⅝ treated, ⅜ controls); and that with two exceptions, located in a herd tested five times and covering only 11 cows, controls were always used.

6. That 39 percent of the controls and 15 percent of the treated cows aborted; that the records in the 31 herds were:

| | Total | Methylene blue | Cresol |
|---|---|---|---|
| **Larger proportion of abortion among controls than among treated cows** | **20** | **14*** | **7*** |
| **Larger proportion of abortion among treated cows than among controls** | **2** | **0** | **2** |
| **Same proportion in each lot** | **2** | **1** | **1** |
| **No abortions in either lot** | **7** | **4** | **3** |

It does not appear that the use of either methylene blue or cresol will inhibit all cases of abortion and no such claim is made or implied. It does not even seem certain that their use will tend in that direction. But it does seem reasonable to conclude, in view of the outcome, that in this particular investigation their use was followed by a somewhat lowered percentage of abortion. Whether this "following" was an effect produced by, induced by, consequent upon a definite cause, namely, the employment of methylene blue or cresol or was merely a chance occurence, does not appear; but the figures shown above—20 herds on the one side and four herds on the other, 39 percent abortion among controls, 15 percent abortion among treated cows, at least furnish food for thought.

No untoward results of any kind were observed in connection with the use of cresol. It is harmless, inexpensive, readily employed and is not a self advertiser as is methylene blue. Such being the case, it would seem to be worth using—not by itself, far from it—but in connection with the prophylactic treatment commonly advised and set forth on pages 29 to 31 and the maternity stable (page 31).

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***Both methylene blue and cresol used in one herd.**

## II. TWENTY-EIGHT YEARS' EXPERIENCE IN THE UNIVERSITY HERD

The University herd was established in 1888. It was destroyed early in 1894, almost every animal being tuberculous, as is set forth in bulletin 42. A new herd was purchased during the spring of that year.

For 15 years from 1892 to 1906, inclusive, herd records were annually published in the station reports. The herd ranged in size from 17 to 74, averaging from 1897 to 1906, 63 in number. A relatively large proportion of the cows were bought and relatively few were raised during this decade. Cows were cheap in those days, they came and went, some youngsters were raised and other ones passed on. Beginning in 1907, the prolonged feeding trials were started upon the results of which bulletins 225 and 226 were constructed, and no more herd records as such were published.

The mass of records kept during these 29 years enable the presentation of the following table setting forth the situation in respect to the prevalence of abortion in the herd.

| | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | | * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bettie .............. | A | A | | A | C | C | S | | | | | | | | | | 3/5 |
| Dora ............... | C | A | C | C | S | | | | | | | | | | | | 1/4 |
| Jeannie ............. | C | A | | C | C | C | S | | | | | | | | | | 1/5 |
| Jessaline ........... | C | A | C | D | | | | | | | | | | | | | 1/3 |
| Kinkora ............ | C | A | B | S | | | | | | | | | | | | | 1/2 |
| Lady LeBrocq ...... | C | A | A | B | S | | | | | | | | | | | | 2/3 |
| Effie ................ | | C | A | B | S | | | | | | | | | | | | 1/2 |
| Flox ................ | | C | A | F | D | | | | | | | | | | | | 1/2 |
| Clover .............. | C | C | | A | | C | S | | | | | | | | | | 1/4 |
| Maizie .............. | C | C | C | A | C | | S | | | | | | | | | | 1/5 |
| Max Belle .......... | | | C | A | A | A | C | C | C | C | S | | | | | | 3/8 |
| Brownie ............ | C | C | | C | A | S | | | | | | | | | | | 1/4 |
| Ceres ............... | | | | C | A | C | C | | C | C | C | C | C | | C | S | 1/10 |
| Lady Perusia ...... | | | | C | A | | C | C | C | | C | | C | S | | | 1/7 |
| Jersey Lily ......... | C | C | | C | C | A | C | S | | | | | | | | | 1/6 |
| Minta Bella ........ | | | C | | C | A | C | C | C | C | C | C | C | S | | | 1/10 |
| Atalanta ........... | C | C | C | C | C | | C | A | A | C | S | | | | | | 2/10 |
| Sonoma ............ | | | | | | | | | A | | C | C | C | S | | | 2/5 |
| Star Bright ......... | | | | | C | C | C | C | A | A | C | S | | | | | 2/7 |

| | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mona .............. | C | C | C | | A | C | C | A | C | C | C | S | | | | | 2/10 |
| Beautina ........... | C | C | | C | C | A | S | | | | | | | | | | 2/5 |
| Ursula ............. | | | | C | C | A | S | | | | | | | | | | 1/3 |
| Alta ............... | | | | | C | C | A | C | C | | C | C | C | C | S | | 1/9 |
| Ardelle ............ | | | | | | | A | C | C | C | | C | C | | C | C | |
| " *............ | A | C | S | | | | | | | | | | | | | | 2/10 |
| Constance .......... | | | | | C | C | A | B | S | | | | | | | | 1/3 |
| Dolly ............... | | | | | | | A | B | S | | | | | | | | 1/1 |
| Sabra .............. | | | | | | | A | C | C | Mnt | | A | C | C | S | | 2/6 |
| Serena ............. | C | C | C | C | | A | A | C | S | | | | | | | | 1/7 |
| Laura .............. | | | | C | | C | A | B | S | | | | | | | | 1/3 |
| Euclina ............. | | | | | | | A | | C | C | S | | | | | | 1/3 |
| Gray Beauty ........ | | | | | | | C | A | S | | | | | | | | 1/2 |
| Jane ............... | | | | | | | | A | C | Mnt | | C | C | D | | | 1/4 |
| Mattie .............. | | | | | | | | A | A | C | C | S | | | | | 2/4 |
| Mermaid ........... | | C | | C | C | C | C | A | | C | A | S | | | | | 2/8 |

| | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marygold ........... | | | | C | A | S | | | | | | | | | | | 1/2 |
| Myrtle .............. | | | C | C | A | S | | | | | | | | | | | 1/3 |
| Sheila .............. | | | C | A | A | C | C | C | A | C | C | C | C | S | | | 3/11 |
| Yemassee ........... | | C | C | C | A | C | S | | | | | | | | | | 1/5 |
| Cassandra .......... | | | C | C | C | A | A | B | S | | | | | | | | 2/5 |
| Joanna ............. | | | | | | A | S | | | | | | | | | | 1/1 |
| Mildred ............ | | | | | C | A | A | A | C | C | C | C | S | | | | 3/8 |
| Stella .............. | C | C | | C | A | A | D | | | | | | | | | | 2/5 |
| Valentine ........... | | | C | C | C | A | S | | | | | | | | | | 1/4 |
| Vt. Aster ............ | | | | | | A | C | A | | C | C | A | S | | | | 3/6 |
| Mab ................ | | | | | | C | A | C | C | C | C | C | | S | S | | 1/8 |
| Perusia Lady ....... | | | | | C | | A | S | | | | | | | | | 1/2 |
| Peggy .............. | | | | | | C | A | C | C | A¹ | D | | | | | | 1/4 |
| Rocket ............. | | | | | | C | A | A | C | C | C | C | C | A | S | | 3/9 |
| Zuke ............... | | | | | | | A | C | B | S | | | | | | | 1/2 |
| Augusta ............ | | | | | | | C | A | C | C | C | A | C | C | Maint | | |
| " †........... | A | S | | | | | | | | | | | | | | | 3/10 |
| Kate ............... | | | | | C | | C | A | C | C | C | C | C | S | | | 1/8 |
| Hepsy .............. | | | | | | | | A | C | C | C | C | S | | | | 1/5 |
| Yuba ............... | C | C | | C | C | | C | A | C | C | S | | | | | | 1/9 |
| Crystal ............. | | | | | C | C | C | C | A | C | C | C | S | | | | 1/8 |
| Vermont Ivis ....... | | | | | | | | | A | | C | C | C | S | | | 1/4 |
| Santa Rosa ......... | C | C | C | C | | C | C | C | A | C | C | S | | | | | 1/10 |

| | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Angie | | C | C | | A | C | C | C | C | S | | | | | | | 1/7 |
| Vie | | C | | C | A | C | C | A | D | | | | | | | | 2/6 |
| Helen M. | | | | | A | B | S | | | | | | | | | | 1/1 |
| Slicker | C | | C | C | A | C | B | S | | | | | | | | | 1/5 |
| Altje | | C | Mnt | | A | C | C | | A | D | | | | | | | 2/5 |
| Fyra | | C | C | C | C | C | A | C | S | | | | | | | | 1/7 |
| Zeta | C | C | | | C | C | | A | D | | | | | | | | 1/5 |
| Ryllis | | | | C | C | C | C | C | C | C | C | A | C | C | C | C | |
| " ‡ | S | | | | | | | | | | | | | | | | 1/13 |

| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lanta 2nd | C | A | C | Maint | | | | S | | | | | | | 1/3 |
| Lily | | A | D | | | | | | | | | | | | 1/1 |
| Effa | C | | A | C | Maint | | | S | | | | | | | 1/3 |
| Janet | | C | A | | A | C | A | | C | S | | | | | 3/6 |
| Karah | | | A | A | C | C | | | A | C | C | S | | | 3/7 |
| Katydid | | | A | C | C | C | C | C | | C | S | | | | 1/7 |
| Kinky | | | A | C | | C | C | A | C | | C | | C | | 2/8 |
| Vermont Dorcas | | | | A | A | S | | | | | | | | | 2/2 |
| Emma | | | | A | | A | S | | | | | | | | 2/2 |
| Granny | | | | A | C | C | S | | | | | | | | 1/3 |
| Maud | | | | A | C | Maint | | | C | C | C | A | C | S | 2/7 |
| Rena | | | | A | C | C | C | C | C | C | K | | | | 1/7 |
| Tops | | | | A | | A | S | | | | | | | | 2/2 |
| Ulta | | | | A | D | | | | | | | | | | 1/1 |
| Alice | | | | A | | C | C | C | C | C | | C | C | | 1/8 |
| Cora | | | | C | | A | C | C | A | A | | A | S | | 5/8 |
| Hattie | | | | | | A | | A | C | C | C | C | C | | 2/7 |
| Hote | | | | | | A | | C | C | S | | | | | 1/3 |
| Robin | | | | | | A | AA | C | C | C | C | C | C | | 3/9 |
| Beth | | | | | | | A | C | C | C | S | | | | 1/4 |
| Joan | | | | | | | A | C | C | C | C | S | | | 1/5 |
| Joan Hill | | | | | | | A | C | C | | C | C | C | S | 1/6 |
| Laura B. | C | | C | C | C | A | A | C | B | S | | | | | 2/7 |
| Nesbit | C | C | C | Maint | | | A | | C | C | | C | S | | 1/7 |
| Ruth | | | | | | C | A | S | | | | | | | 1/2 |
| Raymie | | | | | | C | A | C | C | C | | C | S | | 1/6 |
| Vermont Monona | | | | | | C | A | S | | | | | | | 1/2 |
| Zoe | | | | | | C | A | A | C | C | C | C | S | | 2/7 |
| Belle | | | | | | | | A | | C | C | C | C | S | 1/5 |
| Lin | | | | | | C | C | A | C | C | C | C | C | | 1/8 |
| Carrie | | | | | | | | C | A | | C | | C | | 1/4 |
| Constance 2nd | | | | | | | | | A | A | K | | | | 2/2 |
| Derby | | | | | | | | | A | C | C | | C | C | 1/5 |
| Lady Netherland | | | | | | | | | A | C | S | | | | 1/2 |
| Laura's Gem | | | | | | | | C | A | A | C | S | | | 2/4 |
| Isadore | C | C | | C | C | C | Mnt | | A | | A | S | | | 2/7 |
| Nina | | | | | | | C | C | A | S | | | | | 1/3 |
| Vermont Muriel | | | | | | | | C | A | C | | S | | | 1/3 |
| Vinegar | | | C | C | C | C | Mnt | | A | | C | D | | | 1/6 |
| Ellen | | | | | | | | | | | | A | A | | 2/2 |
| Arline | | | | | | | | | | | | A | | | 1/1 |
| Cath. Ches. | | | | | | | | | | | | | A | | 1/1 |
| Daisy H. | | | | | | | | | | | | | A | | 1/1 |
| 471 | | | | | | | | | | | | | A | | 1/1 |
| Nora | | | | | | | | | | | A | S | | | 1/1 |

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NOTE.—In 1907 a cow not belonging to herd aborted.

[1] Accidental.

S, sold; B, barren; D, died; K, killed; F, farrow; Maint or Mnt, cow kept dry, being used in maintenance studies (Bul. 228).

*This fraction indicates the number of abortions in total calvings including abortions. Thus, Bettie 3/5 and Dora 1/4 means that Bettie aborted three times out of five and Dora once in four times.

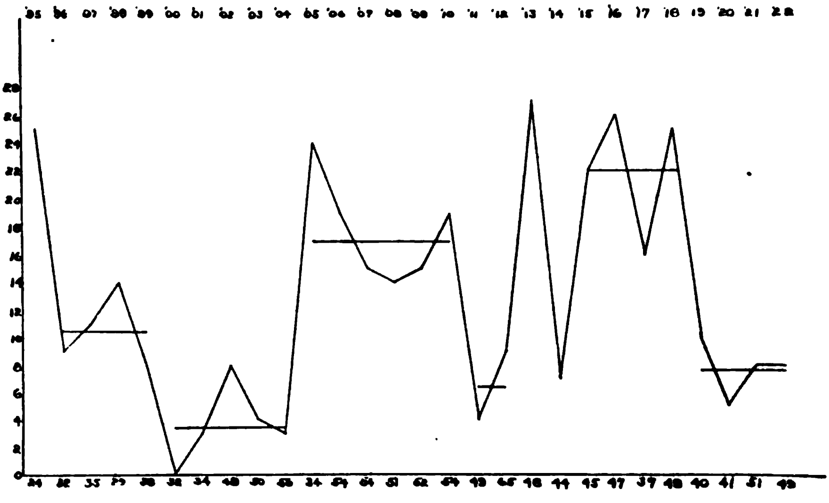
†1917 and 1918; ‡1921.

The condensed data follow:

| Year | Normal calvings | Abortions | Abortions | Year | Normal calvings | Abortions | Abortions | Year | Normal calvings | Abortions | Abortions | Year | Normal calvings | Abortions | Abortions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % | | | | % | | | | % | | | | % |
| '95 | 18 | 6 | 25 | '02 | 44 | 4 | 8 | '09 | 44 | 8 | 15 | '16 | 35 | 12 | 26 |
| '96 | 29 | 3 | 9 | '03 | 48 | 2 | 4 | '10 | 44 | 10 | 19 | '17 | 31 | 6 | 16 |
| '97 | 31 | 4 | 11 | '04 | 54 | 2 | 3 | '11 | 47 | 2 | 4 | '18 | 36 | 12 | 25 |
| '98 | 25 | 4 | 14 | '05 | 27 | 8 | 24 | '12 | 59 | 6 | 9 | '19 | 36 | 4 | 10 |
| '99 | 35 | 3 | 8 | '06 | 44 | 10 | 19 | '13 | 35 | 13 | 27 | '20 | 39 | 2 | 5 |
| '00 | 32 | 0 | 0 | '07 | 46 | 8 | 15 | '14 | 41 | 3 | 7 | '21 | 47 | 4 | 8 |
| '01 | 33 | 1 | 3 | '08 | 44 | 7 | 14 | '15 | 35 | 10 | 22 | '22 | 45 | 4 | 8 |

The accompanying graph sets forth the fluctuations more clearly than does the tabular statement. However, the following brief résumé may also be of service.

TWENTY-EIGHT YEARS' EXPERIENCE WITH ABORTION



Years at top; total average number of mature cows in herd for each year at bottom; percentage of total number aborted at left.

'95. Many abortions ensued—one in four—when the new herd was bought from several sources.

'96-99. Then followed a four-year period during which time one cow in 10 aborted.

'00-'04. Then came a five-year period during which time only one cow in 30 aborted.

'05-'10. Then ensued a six-year period during which one cow in six aborted.

'11-'12. The fire having pretty much burned out—looking at it one way—during two years only one cow in 16 aborted.

'13. Then followed a devastating year during which every fourth cow aborted, i. e., 27 percent.

'14. Then calm succeeded storm and for a single year only one cow in 14, instead of one in four aborted.

'15-'18. Then ensued four devastating years in succession, during which time every fifth cow aborted, i. e., 22 percent.

'19-'22. And, finally, during the past four years, only one cow in 13 has aborted.

During this long term of years, 108 different cows have aborted, the total number of such mishaps being 158 (1.46 per cow). Seventy-one cows aborted once, 26 twice, 10 thrice and one no less than five times. On a percentage basis the figures were 66, 24 and 10. One cow in three which aborted once aborted twice, and one cow in three which aborted twice aborted thrice. The proportion of repeaters to the entire number did not change materially as the years went on, the tendency being slightly to increase the proportion. Twelve cows, having aborted early in life, thereafter calved normally two or more times and then again aborted. Two-thirds of these were located in the pre-war period. Twenty-two cows calved successfully four or more times after aborting, 18 having aborted once, one twice, three thrice.

Comparatively little abortion occurred among the younger members of the herd in its early days, i. e., 1895-1904, but much more since 1904. The figures are as follows:

| | Two-year olds | Three-year olds | Mature cows |
|---|---|---|---|
| 1895-1904 ...................... | 0 | 2 | 27 |
| 1905-1922 ...................... | 22 | 22 | 85 |

This is a striking difference; and "there's a reason." In the first place, the writer feels uncertain as to the entire accuracy of the records during the first decade in respect to the abortions of young animals entering the herd. Then, too, relatively few were raised, only 33 being kept for more than a year after calving during the 10 years. Many times this number were raised during later years. Cows were cheap in the late nineties and purchase common. The situation obtaining in the 1905-1922 period, unfortunately, is more nearly typical.

What relation, if any, did remedial treatment, barn disinfection, etc., have to these very pronounced fluctuations? What relation did acquired immunity have?

No definite answer can be vouchsafed. However, in a very general way the history of the herd can be set forth in respect to attempted methods of control. It should be stated—not in the least by way of criticism but simply as a record of fact—that during much of the time the writer could do no more than suggest. His suggestions were sometimes heeded, sometimes disregarded. Barn hands, careless, ignorant, often disregarded instructions and in a few minutes undid all that painstakingly had been done. However, the writer has had general oversight of the health and well-being of the herd for 30 years and out of that experience can make the following general statements:

'92-'93. During the winter, 13 cows were in calf and due to calve by mid-spring. On November 20, December 15, 16 and January 3, four of the 13 aborted. The then station director states that "the stable was thoroughly disinfected by burning sulphur, the fumes being kept in the barns for about two hours," thrice within four days. . . . . "During the next few weeks about half the cows in calf were kept continually under the influence of laudanum and a careful watch kept of all. Three cows showed signs of aborting and in each case they were at once given large doses of laudanum and kept fully under its influence until the signs of uneasiness ceased. All the nine cows passed through their full time and dropped good, healthy, vigorous calves."[1] The writer does not feel that the slightest stress need be laid on this observation, which is included here simply to complete the record. He does not recommend laudanum for this purpose.

'93-'12. During this long period more or less attempt was made to combat this disease without much avail. Carbolic acid was injected subcutaneously at one time and another at ten-day to two-week intervals, but without apparent result. The cows were douched with weak bichlorid solution at times, repeating the treatment for a while at weekly or biweekly intervals. This sometimes caused vaginal or uterine irritation and induced straining, but, apparently, not abortion. Annually for a long series of years following the tuberculosis holocaust of 1894, the cow barn, walls, ceiling, floors, stanchions were thoroughly cleansed and bichlorid freely used, upwards of ten barrels of solution being employed each time. The bad years of '95, '98, '05-'10, in which much abortion occurred, were included within this period of annual barn cleansing. It doubtless did good in a general way but did not reach the seat of the trouble.

'12-'13. During the fall of 1912, the results of the laboratory tests of the effect of methylene blue upon the abortion organism suggested the direct use of this chemical. During 18 months (1911, January-June, 1912) only two mishaps had occurred. Then came the deluge. Three cows miscarried in July and September and three more in December. Complement fixation tests were made and 30 cows treated with the blue. One aborted in April and a few others some time later and during the ensuing summer, five heifers aborted, four of which had been treated.

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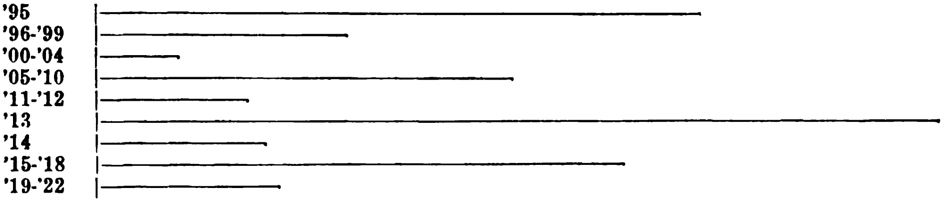
[1] Vt. Sta. Rpt. 6, pp. 114-115 (1892).

'14-16. During this time little effectual work was done to curb the malady. Barn hands did not follow directions and attempts to control infection of the premises were defeated.

'17-'22. Beginning in January, 1917, and sporadically since that time, cresol (U. S. P.) has been used, mixed with molasses. It was fed to the cows for a few weeks once a day. The proportions used were one to three. Neither more nor less would serve, as the two fluids separated when mixed in other proportions. As a rule, the heifers were fed the cresol-molasses mixture before they were sent to pasture. It has been fed quite commonly for a few weeks in December of late years. Neither vaccines nor bacterins have been used at any time.

The writer is frank to say, looking back over his more than a quarter of a century of experience with this disease in this and other herds, that he is far from certain that any necessary, certain and pronounced relationship between the use of drugs on the one hand and the control of abortion on the other has been discovered. As is pointed out elsewhere (page 8) the use of methylene blue or of cresol in 31 herds where controls have been left has been followed by a lessened percentage of abortion in the vast majority of cases. Whether this "following" is significant or not he is not prepared to say. However, cresol feeding does no apparent harm and hence seems worth using.

In a general way, it seems to the writer that the horizontal lines in the graph on page 12 and transferred here, represent fire and ashes; infection and acquired immunity. His associate, the university farm superintendent, pins his faith on cresol since now for four years (1919-1922) the abortion figures have been low; but the writer, with 1900-1904 and 1911-1912 in mind, takes counsel of his fears rather than of his hopes.



## III. THE CONTROL OF THE DISEASE

What is the nature of the bovine malady variously termed "contagious abortion," "infectious abortion," or, better, "abortion disease?" How much damage does it do? What causes it? How do cows become infected? How does it spread from cow to cow? What are its symptoms? What happens when a cow aborts? How can one tell whether or not a cow is going to abort? How can one determine the presence or absence of infection in the herd? What can be done by way of treatment, of prevention, of control, of cure?

### NATURE

This malady is an infectious disease. It normally occurs among and is communicable among cattle which seem to be the true host of its causal germ. A cow thus affected may or may not abort. Whether she aborts or calves normally she may infect others. The premature expulsion of the fœtus from the uterus, which is a result, the supreme result so to speak, of the disease, may occur at almost any stage of conception, so early as almost if not quite to escape notice, or so late that the cow nearly attains the period of full-time calving.

The disease is not contagious but infectious; that is to say, it is not "transmissible by contact" direct or indirect with a cow harboring the germs which cause it—which constitutes contagion—but transmissible by virtue of some common environmental condition, the germs being carried from one individual to the other, for example, through the medium of the air, or water—which constitutes infection.

The disease does not seem to be transmissible to domestic animals other than cows, guinea pigs and rabbits. Mares and other animals abort because of infection, but this is the result of attack by germs other than the specific one which commonly attacks cows, namely, the Bang abortion bacillus. The cow usually aborts because of infection with this specific organism and sometimes, perhaps, of infection with other organisms.

### DAMAGE

This malady does great damage. It seems to be omnipresent wherever dairying obtains throughout this country, in much of Europe and elsewhere. It is no new disease, having been recognized in England as long ago as 1567. It is said by good authority to be more widespread than any other bovine ill, to have infected the majority of the purebred herds in this country and to be common among beef cattle, even among those on the open range. It is a freaky disease. It may ravage a herd, disappear slowly or perhaps suddenly, lie dormant for years and then break forth again with almost startling suddenness. The infection may be mild or virulent. A cow or two may abort or it may sweep through the herd.

## NATURE OF THE DAMAGE

The damage it does is both direct and indirect. Not only is herd replacement retarded, not only is the milk flow seriously impaired, but either repeated abortion, delayed breeding or absolute sterility are apt to ensue. Furthermore, as is indicated later on, treatment, if attempted, is laborious, time consuming, costly and far from certain. If a cow aborts before the fifth month of pregnancy the milk flow does not readily respond to the stimulus, whereas if it occurs at a later time the cow is very apt to become unprofitable. Indeed, the average cow may often be sold for beef to better advantage in lieu of being kept for another period of nine or more months, making a relatively small amount of milk, being for a few weeks a distinct menace to her stable associates and, perhaps, finally proving barren or aborting again in case she conceives. The several sequelæ of abortion (retained afterbirth, vaginal discharge, possible blood poisoning, the change of the temporary catarrh into a permanent condition) all tend to induce repeated abortion, delayed breeding or ultimate sterility.

There appears to be greater likelihood of loss among registered cows than in grade herds. The widespread traffic among purebreds encourages its spread and it seems reasonable to assume that intensive breeding and high productivity tend to induce greater susceptibility. Furthermore, the loss of a purebred calf is a more serious matter than that of a grade. Then again the highly important movement is retarded whereby through the introduction of purebreds into grade herds, the quality of the stock is improved, for there are less calves to sell and buyers are less likely to purchase. And, of course, the delayed breeding and sterility which often follow are added and even more serious handicaps.

The malady is no respecter of breeds, although breeds within which the greatest traffic occurs naturally suffer most. Under equal conditions equality in respect to susceptibility seems probable.

It is on these accounts that many authorities hold that this disease is an even more serious menace to the wellbeing of American dairying than is the great scourge of bovine tuberculosis, and that it exacts a heavier toll. Certain it is that the after-effects are much more far reaching and that its control is more more difficult.

### EXTENT OF THE DAMAGE

The extent of the direct as well as the indirect losses caused by abortion can only be conjectured. Hadley (1918) estimates that eight percent of all milking cows abort annually. The writer is on record in 1913 as saying "that the claim that one percent of Vermont cows abort annually is probably an understatement." Accepting it, however, as valid, this means 3,000 aborting cows, 3,000 less calves, probably 3,000,000 pounds less milk made annually and at least $100,000 damage done annually in the comparatively small State of Vermont.

### Cause

This malady is caused by infection due to a specific germ, the abortion bacillus of Bang, originally discovered by this investigator in Denmark. It has been repeatedly isolated elsewhere. Other organisms closely similar to it have been found which bear a relationship to abortion in other domestic animals. A spirillum has been isolated by Smith in this country and a vibrio by Stockman and McFayean in England, which are deemed by them to bear relationship to infectious bovine abortion, that is to say, to be causative factors in some instances rather than, or perhaps rarely in associationship with, the Bang bacillus. It may be that various septic and pyogenic bacteria, even ordinary parasitic organisms, perhaps toxic substances of an emmenagogic nature, may rarely function, but some of our best authorities are skeptical as to this possibility. However, it is generally held today that there is only one common and widespread causal factor, namely, the Bang abortion bacillus.[1] It is possible that occasional abortions are due to accident, i. e., slipping, goring, falling, etc., but such cases are very rare. Spoiled, ergotty or smutty grain or roughage are sometimes thought to induce abortion, but there is no definite proof that such is the case and considerable evidence to the contrary. Excessive or exclusive use or wheat products has experimentally induced abortion, but the rations fed were abnormal. Certain it is that a breeder may safely assume that a sporadic case is due to infection and proceed accordingly.

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[1] Smith (Jour. Exp. Med., 30. 4. pp. 299-357, 1919) holds that "relatively few cows are subject to disease of the fœtal membranes due to the *B. abortus*, twice. * * * Abortions do occur in succession but they are due chiefly to causes other than *B. abortus*. * * * Were it not for agents other than *B. abortus*, such as *Vibrio fetus* and to a far less degree to miscellaneous septic and pyogenic organisms and to unknown nonbacterial agencies, second and later abortion by the same cow would be relatively rare." If Smith's contention is upheld as a result of further investigation, it would seem logical to assume that almost every cow aborting for the first time because of infection with the Bang bacillus would acquire, so far as that particular organism is concerned, a greater or less degree of natural immunity. Furthermore, it would seem logical to expect that if a Bang vaccine were needed in the first instance, a Smith vaccine should be used on such cows as have aborted once as a deterrent to the action of the vibrio and, perhaps, a mixed-infection vaccine to protect against "miscellaneous septic and pyogenic organisms." Truly it looks as if, in respect to abortion, the dairyman's life was "just one damn thing after another."

The bacilli are very small, rod-shaped organisms. They enter the body in the first instance almost invariably by way of the digestive tract, being ingested with food or water. It has been held quite generally in the past that the genital tract was a fertile channel of infection, especially at the time of service and that the bull, particularly if he had been used on cows which had aborted, was the prime source of trouble. Occasionally he is at fault, but even when diseased and conveying the organisms to the vagina, it is now believed that they rarely infect the non-pregnant or about-to-become-pregnant animal. It formerly was thought that the udder, which is the most common permanent habitat of the Bang bacillus, became infected via the teat channel, but it is now held that this source of infection is unusual and that udder infection occurs via the blood stream. In short, the present point of view is that to all intents and purposes the only channel of entrance of this germ into the body is the mouth. Once having entered the body, it can readily reach the udder and its adjacent lymph glands and thence pass, when a cow becomes pregnant, to the uterus.

The bacilli grow best in placental tissue, in fœtal tissue, in the vaginal discharges, within the uterus preceding and following abortion, and in the udder. It is difficult to grow them artificially outside the body, where they increase slowly if at all and readily die; but within or in contact with these bodily tissues—particularly under conditions of moisture and opacity—they may live for months. Their favorite abiding places are in the outer layers of the placenta, or afterbirth, that is to say the chorion or chorionic epithelum, in the udder and in the adjacent lymph glands. In the latter location they increase slowly in number, but they multiply so rapidly under the ideal conditions obtaining in the pregnant uterine cavity as to inhibit the proper nutrition of the fœtus by the mother. She can not properly feed her unborn young and, as a result, it sometimes is prematurely expelled. All too often the afterbirth is retained, inflammation ensues, pus forms and either delayed breeding or permanent sterility occur. The germs are readily killed by the rays of direct sunlight, but they may live for months in moist places and will resist freezing for many months.

The Bang bacillus is a versatile germ. It varies in virulence from time to time and as between strains. Furthermore, some cows are much more resistant than are others to the inroads of the disease and the resistance of a given cow may change from time to time, it being more susceptible, for example, today than it may be a month later. Hence it is that sometimes abortion follows upon the very heels of infection, while sometimes it happens late in pregnancy or not at all; that sometimes the cow aborts so soon after conception as to be almost unobserved, while sometimes she waits until the very last moment before the mishap occurs.

## METHODS OF TRANSMISSION

### THE COW

It is often difficult to tell how the disease enters a given herd. Once established it is doubtless more often conveyed from cow to cow and through the herd because of the presence of the germs in the vaginal discharges of an aborter than in any other way. These discharges teem with the Bang bacilli just before and after abortion.

There are four known sources whence the abortion bacilli are derived:

1. The vaginal discharges from the uteruses of infected cows at and following parturition. This is far and away the main source of trouble. When a susceptible pregnant cow gains access to and swallows material infected with the abortion bacilli, she is very apt indeed to become herself infected and, being infected, reacts and all too often, though not always, aborts.
2. The milk or milk by-products of cows whose udders are infected.
3. The fecal discharges of unweaned calves dropped by and suckled by infected cows.
4. The seminal fluids of bulls with infected reproductive organs.

A cow which calves normally may be as effective a spreader of the disease as is the so-called "aborter" herself. Udder infection may occur and a cow calve normally. Indeed, udder infection is said by good authority to be extremely prevalent. Some go so far as to say that approximately half the cows with infected udders have infected uteruses at calving. Udder infection may cease in a few weeks or persist during most of the cow's life; and in the latter event it is possible, though not probable, that she may calve normally throughout her mature life. There is no evidence to indicate that the presence of the abortion organism in the udder causes any lesion or that the milk is pathogenic. Furthermore, there is experimental evidence to warrant the belief that a more or less profuse discharge of the abortion bacilli occurs from the vagina following upwards of half the normal calvings of cows with infected udders. They last in the uterus for a short time only, rarely for more than three weeks. This means that seemingly healthy cows may be and often are "carriers," the abortion organisms passing more or less continuously from their bodies in relatively small numbers in the milk and periodically in large numbers at calving in the vaginal discharges. Everyone has heard of that unfortunate woman, "Typhoid Mary," a veritable harborer and harbinger of death. Everyone now appreciates the danger due to the presence, of a "typhoid carrier" or a "septic sore throat carrier" on a milk route. There are doubtless countless millions of unsuspected Abortion Bossies all over the world. Fortunately their bacterial outpourings do not seem to be pathogenic in any respect whatsoever to the human kind.

## THE BULL

Popular belief to the contrary notwithstanding, the bull is not very often at fault. He may sometimes serve as a mechanical carrier of the disease, that is to say, he may possibly transmit it to an uninfected cow, if he has served one who is infected. However, this is not likely to happen. In the first place, even if an infected cow is served the first time she comes in heat following calving or abortion, she is not likely to harbor many, if any, abortion organisms in her vagina for the reason that they almost always disappear within three weeks; and in the second place, since the bacilli do not seem to live for any length of time in the non-pregnant or newly impregnated uterus, but to multiply, if at all, only in a temporary and at that time non-existent tissue, namely the chorion of the placenta, obviously there is little danger of infection occurring as a result of service. The bull is less likely to be infected than is the cow, but such infection is not uncommon. However, infection is one thing and the transmission of such infection to the cow is another. It is sometimes advised to flush the sheath with a weak antiseptic solution, using a soft rubber tube attached to a funnel. This may serve to lessen the likelihood of mechanical transmission, but will in nowise affect matters if there are lesions of the seminal vesicles, a condition which sometimes happens.

Until within a few years, it was quite generally held that the main channel of infection was the nearby and obvious one—the vagina—and that the bull was a prime agent in the spread of the disease. This inference has been most thoroughly disproved as a result of extensive and seemingly conclusive tests. Into the uteruses of abortion-free cows have been introduced all sorts of infected material, including pure cultures. They have been served by reacting bulls, by bulls which just previously had served cows with infected genital tracts, by bulls both naturally and artificially infected in the genital organs—all with negative results, neither reaction nor abortion occurring. There seems to be but one conclusion to be drawn from these trials, namely, that the cow's genital tract is not a normal channel of the entry and that her non-pregnant or freshly impregnated uterus is not a normal abiding place of the Bang bacillus. As a corollary of this observation it may be concluded that a community bull, a "bull association" bull can be safely and freely used if he himself is not infected. A bull from a herd in which abortion has been rife is, of course, more likely to have become infected than one coming from a clean environment.

No dairyman should dispose of a good bull on suspicion only, hoping thus to check the disease. He may be only an innocent bystander. He should be tested first as to the presence or absence of the organisms.

## RAW MILK

Raw milk at times may convey the disease to other bovines. So far as is known the organism is not pathogenic to the human kind. Because of this possibility and in the interests of the control of the disease and in order to lessen the likelihood of dispersal, it is advisable to require pasteurization of all dairy-plant by-products before they are fed. Such a procedure, legally required and strictly enforced, would materially curtail the dissemination of tuberculosis and might be serviceable in lessening the spread of abortion. Furthermore, it should be noted that an aborting cow may later on become a "carrier," her milk containing the germs for years. Indeed, as has been heretofore pointed out, the milk of cows which have never aborted may carry the infection.

## INFECTION

The malady is infectious. It has been held in the past that cows may become infected via the vagina in the first instance near the time of service or later, though this is not likely to happen after the uterine seal is formed. This source of infection is not now deemed important. Calves may become infected before birth, if born of an infected cow. Whether born infected or uninfected, if fed raw milk carrying the organisms, calves may or may not become infected as a result, with the probabilities perhaps in favor of non-infection. Pregnant heifers, doubtless, are less disease resistant than mature cows and are on this account more liable to infection than are either calves or cows, being particularly prone thereto shortly after the first calving, although those aborting at the first parturition obviously become infected at an earlier date. Hadley states that more than 80 percent of the infections in a large number of herds occurred before the second calving and that 195 of 1.238 pregnant heifers in a very large herd (16%) aborted.

The usual—although perhaps not the exclusive—method of ingress and progress of the Bang organism is thought to be as follows: By ingestion through the alimentary canal, through the intestinal mucosa into the lymphatic system, the blood stream and to the udder, thence when the cow becomes pregnant via these systems to the outer placental layers. The only permanent bodily structures which act as a common habitat is the udder of the female and the adjacent lymph glands and, very much less commonly, the reproductive organs and seminal fluids of the male. Increasingly the veterinary profession is coming to believe that the uterus as such is not its natural habitat—never when not pregnant and rarely when pregnant—but that, on the contrary, the temporary placental structure is its temporary abiding place.

Phrasing this thought in another way, it is now held by some of the best authorities that infectious abortion disease pertains neither to the cow nor to the fœtus but to a temporary structure, namely, the outermost of the fœtal membranes. The cause of the disease is often resident in the cow, that is to say the bacilli often live in the udder and adjacent glands, but the disease itself does not attack the cow or its calf, but the temporary tissue of the afterbirth. This view of the case helps one to understand why it is difficult to treat the cow if the cow, even though she abort, is not diseased; why immunity is developed, if at all, somewhat slowly and unsatisfactorily. The premature expulsion of the fœtus, i. e., abortion, is only a symptom, the essential result of the disease but not the disease itself. It is in a way analogous to the so-called "peeling" of the skin of a scarlet fever patient. The skin patches thrown off by the body are not the disease but one of its manifestations. If fœtal nutrition is not too seriously interfered with, the calf is born at full time, infection to the contrary notwithstanding. Furthermore, some cows are doubtless more disease-resistant than others. They possess more immunity, which may be natural and inherent, or, if they previously have been "aborters," it may be acquired. This fact helps to explain why some cows reacting to the agglutination or complement fixation tests calve at full time. Such cows, furthermore, harboring the organism and throwing it off, themselves unaffected, may endanger their stable mates immediately following calving.

## SYMPTOMS

The symptoms of the malady are all too well-known to Vermont dairymen. Little or nothing happens by way of external evidence if the mishap occurs during early pregnancy. If it happens later, however, the udder swells and the external genitals become congested. If the afterbirth is retained, this discharge becomes offensive. However, often a cow is infected and shows none of these symptoms, calving normally. In other words, infection does not necessarily entail abortion, although such is a common result. Cows which in spite of infection calve normally, usually possess natural immunity or acquired immunity, being or becoming relatively disease resistant in so far as the abortion organism is concerned. Sometimes the fœtus is retained after its death and "mummifies." Sometimes when born at full time it is such a weakling, owing to insufficient placental nutrition, that it dies. And, as has been remarked, sometimes all goes well notwithstanding infection. Hence it is that the number of abortions does not accurately measure the extent of the disease in the herd.

## DETECTION

The presence of the disease in a herd can be detected with a fair degree of certainty well in advance of any abortion. Tests have been devised wherewith one can separate the sheep from the goats, the cows which are from those which are not infected. There are two such tests, both using the blood of the suspect as a means of diagnosis. They are known as the complement fixation and the agglutination tests. The presence or absence in the blood of certain substances produced as a result of infection with the abortion organisms is manifested by their application. The tests are complicated affairs and can be made only in a specially equipped laboratory and by a trained observer. They are reliable, although not infallible, and seem to be equally efficient. They do not indicate that a cow will abort. She may already have aborted, she may be destined to abort or she may never abort. The tests can not foretell the future. All that they do is simply to betray the presence or absence in the blood stream of the so-called antibodies which are produced as a result of the more or less recent presence in the cow's body of the abortion bacilli. They show quite surely.

in other words, whether or not a cow has or has had abortion organisms in her system. At the Wisconsin station, 36 percent of more than 6,000 cows tested by these tests reacted and 59 percent of more than 1,700 tested at the Vermont station reacted. The blood of a cow which has aborted will react before the mishap and continue to react for a greater or less length of time thereafter, sometimes becoming "negative" promptly after abortion and sometimes remaining "positive" for a series of years.

### SEC. 514 G. L.

Section 514, General Laws, provides ready means whereby any Vermonter desiring to know the situation touching his herd, can do so. He can have the blood of each cow in his herd tested for a moderate fee at the State Laboratory of Hygiene, Burlington, Vt. This laboratory has no relationship to the Experiment Station or to the College of Agriculture and samples should be sent only to the State Laboratory of Hygiene. This law has been on the statute books for eight years, but very few calls have been made upon the laboratory for this service. Perhaps Vermont dairymen have become fatalists in respect to the control of this malady; perhaps they feel that the tests have too great limitations and that treatment is too costly, too laborious and none too certain. At any rate, whatever the reason, they do not resort to the laboratory to determine the facts.

### IMMUNITY

Immunity may be either natural, that is to say, inherent, or it may be acquired. It often happens that a person or an animal does not succumb to a disease which is taking its toll by scores and hundreds all about it. This person or animal, moreover, may never have had the disease, possessing in some degree a natural, inborn ability to ward off infection. An animal is said to be immune to a given disease, e. g., abortion, when it is effectively disease resistant to that malady. On the other hand, this immunity may happen because the person or animal has had the disease and thus become immune or because it has been purposely infected with the living disease-producing organism. Such immunity is of the acquired sort. A person who has had measles rarely has measles twice; he has become immunized to measles, he has acquired immunization. A person who is vaccinated rarely catches smallpox, having been purposely infected with a living virus producing an analogous and less dangerous disease, namely, cowpox. An immune animal may or may not be a "carrier," but at any rate it does not itself abort. Now a cow may be able because of immunity to carry her calves through to full time, even though the germs are in her system, in which event premature fœtal expulsion, placental retention, delayed breeding, sterility, do not occur. As has just been pointed out, this immunity may be either natural or acquired, natural, presumably because of the auto-development of protective substances (the so-called and oddly called "anti-bodies"), substances which serve to inhibit the further growth of the abortion germs, or acquired, because of their development as a result of previous abortions or of inoculation. Now, cows do not abort continuously. Many abort once; perhaps one in three or four of those who abort once abort twice; and perhaps one in three or four of those who abort twice abort thrice. The repeats may be due to a hold-over of the original infection, to reinfection or, according to Smith (footnote p. 18), to infection with another organism. The proportion of repeaters thus disclosed is doubtless too low, for many farmers dispose of cows after their first abortion has taken place, sometimes wisely, but often actuated by the mistaken notion that thus they can rid the herd of the disease. Some of these cows, if held in the herd and again conceiving, would doubtless again have aborted. This conceivably would have been due to the fact that the individual was less readily immunizable than the majority of cows. On the other hand, some of these cows if held in the herd doubtless would become as many do become, for the time being at least, sufficiently immunized as a result of a single abortion. This situation, i. e., normal calving subsequent to abortion, is held to be due to the acquirement of immunity. There are differences between cows and herds in respect to this matter. Some seem more resistant than others for reasons which are not always clear, among which may be mentioned variation in virulence of germs, the age of the cows—an aborting heifer is more likely to repeat than a mature cow—the care given them, the efforts made to combat the malady, actual differences in the resistance powers of different cows, the fact that the dose of naturally formed immunizing material—whatever it may be—is insufficient, lack of time wherein to form it, etc.

So far as natural immunity is concerned, it may be said that calves seem to be immune, though they may ingest the bacilli and pass them through and out of the alimentary canal; that this immunity tends to decrease as age advances and the mammary glands and reproductive organs mature; and that heifers and bulls are not apt to become infected unless the premises are in an unsanitary condition and the disease is abundant.

### VACCINES AND BACTERINS

Attempts have been made to confer immunity by the injection, hypodermically, either of living abortion organisms (vaccine) or of dead abortion organisms (bacterin). The theory on which this procedure is based is the same as holds in respect to vaccination for smallpox, namely, the production of a mild form of the disease which, in turn, induces the production of the protective substances (anti-bodies) within the cow's system, which serve, as it were, to abort the abortion organisms which later may gain access through direct infection. Opinion differs as to the merits of these procedures, although the consensus of opinion seems to be that the bacterins have not proven at all satisfactory; yet they are freely offered by commercial houses. However, there are obvious and decided objections to the use of vaccines, namely, rapid deterioration, slow development of immunity, limited extent of time during which immunity lasts, which may be for months and may be for years, usefulness only with unbred animals, danger in handling living disease organisms. Vaccines, if employed, should be placed in the hands only of trained and careful men, thoroughly conversant with the many dangers incident to their use.

Hadley[1] cites the results of immunizing work in England and in Germany in connection with his own work in Wisconsin. The bacterins were found to be uniformly useless but the vaccines appeared to possess definite immunizing values. However, the author is not unduly optimistic over the outcome, although he expresses his belief that the favorable results were not to be attributed to spontaneous cure. On the other hand, Schroeder[2] points out the insufficiency of commercial vaccines. Having purchased 24 samples, the products of five different biological laboratories, all of them alleged suspensions of live abortion bacilli, all of them of recent manufacture and from two to three months from "return date," he subjected them to four simple but searching tests, with the following outcome: 29 percent were grossly contaminated with various microorganisms; 42 percent were either dead, nearly dead, or worse than worthless because of contamination; 79 percent ranged in value from doubtful to worse than worthless. Not unnaturally Schroeder concludes that "vaccination against infectious abortion disease is in an experimental stage." However, there seems some reason to hope that, as has been the case with other vaccines, eventually an effective medium may be secured. It would seem, however, that a greater degree of care than heretofore has been taken must needs be exercised in the preparation of these vaccines together.

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[1] Jour. Ameri. Vet. Med. Assoc., 13 (N. S.), 1, pp. 26-33 (1921).

[2] Jour. Amer. Vet. Med. Assoc., 14 (N. S.), 4, pp. 363-373 (1922).

## REMEDIAL MEASURES

Abortion may be combated—none too successfully, to be sure, but the battle may be waged. There are at least four ways of going at it, namely, (1) doing nothing, (2) selling out, (3) prevention, and (4) cure.

### 1. DOING NOTHING

The *laissiz-faire* system appeals to the fatalist and the inept. Many farmers do nothing whatever. They let the fire burn itself out; they expect the disease to run its course and die out without treatment; they bank on the development of acquired immunity. The direct cost of the system is nil, but the indirect cost is often staggering. Some cows do recover of their own accord, but many do not. The method has little to recommend it.

### 2. SELLING OUT

"Selling out" is rarely advisable, for unless conscientious care is given to stable disinfection, the cows newly introduced into a contaminated environment will be likely to abort, thus starting the unhappy owner once more at the bottom of the hill. Such a procedure resembles raking out the half burned wood from a fire and piling on fresh kindling. Furthermore, aborting cows tend to develop more or less immunity and selling out is on this account inadvisable. Purchases should be made, so far as possible, from abortion free herds on blood test. However, calves may be safely purchased even though the seller's herd is infected if not fed raw milk during the month immediately preceding purchase.

### 3. PREVENTION

Prevention by the ounce is said to cost less than does cure by the pound; but the ounce in this case is bought at a high price and delivery of the purchased article is not guaranteed. Eternal vigilance must be exercised, many hours of hard labor expended and sometimes a none too satisfactory outcome is the result. The malady does not readily yield to remedial treatment, but something can be done which should tend to better the situation.

### *As to Abortion*

When symptoms of approaching abortion appear, or promptly after abortion has occurred, the cow should be isolated, the fœtal calf, afterbirth and contaminated litter destroyed at once and the location saturated with a properly prepared and reliable disinfectant. So long as vaginal discharge occurs, the rump, vulva, thighs and tail should be daily and thoroughly scrubbed with warm disinfecting fluid.

If the afterbirth is retained, a competent veterinarian should be immediately consulted since its prompt removal is vitally necessary. His advice should be sought before any antiseptic treatment or uterine flushing or douching are attempted. These procedures, formerly advised, are much less commonly suggested at present. Indeed, douching the vagina and uterus, which formerly were urged as a necessary procedure, is now thought to be usually not only futile but positively harmful. The afterbirth is often retained because the Bang bacillus and associated organisms induce inflammation. The cotyledons or so-called "buttons" connecting the uterine walls and the placenta usually swell when inflammation sets in and this hinders removal. A lessened milk flow, a lowered live weight, possible blood poisoning, delayed breeding, eventual sterility or even death are the sequelæ.

Careful, persistent attention at this time will lessen the likelihood of sterility or of subsequent abortion. The cow may well be bred at the first opportunity after the vaginal discharge disappears, since, other things being equal, the likelihood of conception is greater. Whether or not this procedure will prove to be economically worth while will depend upon local circumstances. One can afford to do much to check this malady at its outset or at any time if one's herd is especially valuable.

### *As to Sterility*

Sterility may or may not yield to treatment. A good veterinarian should be able to advise as to probabilities in a given case. It is for the owner to say whether the cow is worth the trouble, the game worth the candle.

Sterility is evidenced by repeated failure to conceive. It is often only indirectly due to the abortion organism. It is quite apt to be the result of what is known as a "mixed infection," to the growth of several sorts of microorganisms, especially those producing pus, favored by the lowered vitality or resistance due to the primal infection. A retained afterbirth is quite likely to induce the growth of the pus forming organisms. Other causes, such as high feeding, insufficient exercise or genital malformation, may also be responsible for this condition.

Adequate stable sanitation, an adequate food supply, annual or semi-annual blood tests of each cow, the isolation or removal of all reactors, purchases, if made, of calves rather than of heifers or mature cows and all blood-tested; these are the safeguards which lessen the likelihood of the introduction of infection and tends to control it if introduced. This procedure has worked when rigorously enforced. In some instances sporadic cases have occurred, in which event prompt measures have prevented further spread.

An adequate, well-balanced and varied food supply, with an ample ash content; complete removal of afterbirth; burning or deep burial of the aborted fœtus and of all contaminated bedding; drenching floors. gutters, etc. with disinfectants; isolation of known aborters and of cows harboring the germs; possibly vaccine treatment two months prior to calving; these are safeguards which tend measurably to control the disease when it has a foothold. This procedure has also worked when rigorously enforced. Not that every case of abortion has been aborted but that the sweep of the disease has been decidedly lessened.

It is quite impossible to state how long it will take in a given case, carrying out the procedure suggested, essentially to eradicate the disease. It has taken at least two years in some herds. Many factors enter in to make prediction unsafe, among them being the virulence of the infection, the age of the cows, the possibility of reasonably complete isolation of aborters, of adequate disinfection of the animal and the premises, etc.

## *Stable Disinfection*

Stable disinfection may be accomplished—not absolutely but relatively—by the removal of all loose litter from the floors, mangers, etc., by sweeping and scrubbing all surfaces, including the ceiling and by applying some reliable disinfectant properly prepared. Whitewash, sunlight and adequate ventilation help.

Infectious abortion disease may do less damage as a rule in ill-kept herds, but sanitary precautions, unless based on a clear understanding of the fundamental cause of the disease, can not control it. In short, the identification and isolation at critical times of all carriers and disseminators of the abortion organism, be they "aborters" or not, is the first commandment in the combat with this disease. To whitewash, to disinfect, to vaccinate, to drug, to enlist all the forces of prophylaxis will not be sure to be of avail, if a seeder is left to recontaminate the premises.

### THE MATERNITY STABLE

Pasteurization of milk products fed to calves or pigs and care in respect to milk usage would close that door of infection. However, it is less easy to insure against infection when any and every cow may be a suspect. Schroeder[1] suggests a "maternity stable," a bovine "lying-in hospital" as it were, to which all cows are removed as parturition approaches or abortion seems imminent for housing until all abnormal vaginal discharges have ceased. Obviously, whenever either normal or abnormal calving occurs, everything which can convey the disease, aborted fœtuses, afterbirths, discharges, etc., should be destroyed in such complete fashion as to prevent danger to other cattle, for the reason that every product and by-product of abortion is actually and all by-products of normal calving are potentially dangerous material.

The writer has come to the conclusion as a result of more than 30 years of contact with this disease, that more than any other one thing the isolation of the cow at and following calving is the prime factor, the most feasible method of control. The maternity stable need not be an expensive affair. It well might cost far less than an epidemic of abortion. It separately houses the cow during the two or three weeks when she may be a source of danger to her mates, for the bacilli are not thrown off in large numbers except during this short period.

### 4. CURE

This system naturally appeals to a generation which has faith in drugs. Furthermore, other infectious diseases have yielded to remedial treatment and why not abortion?

Several proprietary or patent medicines are advertised as sure cures, but their use is rarely advised by the veterinary profession. Several suggestions have been made along the line of the use of curative agents by some of the stations. Laudanum, carbolic acid, methylene blue, cresol and other drugs have been employed; vaccines and bacterins have been injected. Apparent or partial successes seem to have been attained in some cases but the certain specific is yet to be discovered. (In this connection note the statements concerning methylene blue, pp. 4-8, cresol, pp. 5-8, and the vaccines and bacterins, pp. 27-28.)

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[1] Jour. Amer. Vet. Med. Assoc. (n. s.) 4, p. 173 (1920).

And yet many still pin their faith on "cures." It is well understood in human medicine that insidious, chronic maladies sometimes seem cured when in reality they are not cured; that apparent or, indeed, actual improvement ensuing when environmental conditions are bettered misleads the patient and his friends as to its cause; that the patent medicine industry is predicated upon this optimistic trait of human nature. Furthermore, as has heretofore been pointed out, the more or less self-limiting nature of infectious bovine abortion is apt to induce an inaccurate estimate on the part of the laity as to cause and effect.

Some day the fight will be won—although at present it is not clear how it will be done. Possibly some veterinarian Coué in due time may induce bovine auto-suggestion and then "day by day in every way" the cow will grow bigger and bigger until full fruition.

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MAY, 1923 BULLETIN 232

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

# STERILITY OF STRAWBERRIES; STRAWBERRY BREEDING

By M. B. CUMMINGS and E. W. JENKINS

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# BULLETIN 232: STERILITY OF STRAWBERRIES; STRAWBERRY BREEDING

BY M. B. CUMMINGS AND E. W. JENKINS

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## SUMMARY

Sterility is a common condition among fruit plants. It assumes divers aspects in different species and varieties. Among the usual manifestations of sterility are: Imperfection in structural arrangements of the sex organs, unequal maturity of the sexes, natural impotency of pollen, imperfect development of male cells, inheritance of sexual defects and separation of sexes, as is common with strawberries.

The cultivated varieties of strawberries manifest nearly all degrees of sexual vitality from absolute sterility on the one hand to complete fertility on the other, although any given variety may possess much constancy in its condition of fertility.

Several years ago Richardson (19) defined six degrees of perfectness or imperfectness as applied to the strawberry:

"1. Females with male organs undeveloped.
2. Females with most of the female organs atrophied or hypertrophied and inefficient, no male organs.
3. True hermaphrodites with both male and female organs undeveloped.
4. Males with the female organs undeveloped.
5. Males with the female organs only developed in a few flowers, generally the first flowers provided in each truss.
6. Flowers with neither organ developed, or with the female organs hypertrophied."

Certain intermediate forms exist that do not seem to conform to any of these classes.

The genus *Fragaria* is a variable one. Botanists do not agree as to the exact limits of the several species. *F. virginiana* and *F. chiloensis,* the accepted parents of the commonly cultivated varieties, show much variation in their structural parts and in respect to functional attributes.

The early and some of the recent literature of the strawberry suggests some connection or relation between the sex of the plant and the nature of its environment. Such varieties as Stirling Castle, Crescent, Keens' Seedling and Royal Hautbois are reported as showing diverse degrees of fertility in different places, a circumstance similarly reported among apples, pears and cherries.

Nutritional experiments carried on at this Station, using different soils with increasing amounts of a high grade commercial fertilizer and with nitrate of soda and with carbon dioxid used as an aerial fertilizer, do not seem in any respect whatsoever to have induced modification of the sexual structure of the plants or to have made them more fertile or less sterile.

Sterility in the individual flowers of a truss may be associated with structural defects in pollen cell development, but with many varieties it is manifested in the dissociation of the sexes, a condition which antedates the creation of the cultivated varieties and is to be found among the native. and exotic parent-species. In some cases it is due to the unequal maturity of the sexes.

It is possible to trace the unisexual structure of many varieties of the strawberry to the parent variety or even to the parent species. The unisexual condition is common among *F. virginiana* and *F. chiloensis*. In 81 instances among pistillate varieties of known history listed by Fletcher (9) it has been possible to find an immediate parent, a grandparent or a great-grandparent that was also pistillate. Hovey, Wilson, Sharpless and Crescent, pistillate varieties of the early days, have been the progenitors respectively of 51, 41, 69 and 63 pistillate varieties. Several breeders of new varieties have reported the origin of new pistillate varieties among the progeny secured.

The question whether the bisexual or the unisexual type is the more primitive form is a moot one. It may never be settled. However, this is a somewhat remote point in reference to this general problem of sterility, although obviously it is of general scientific interest.

In the course of the conduct of the trials herein reported, breeding experiments were conducted with large numbers of plants over a series of years in order to ascertain the behavior of sex when perfect and imperfect flowered varieties were crossed. Nineteen thousand, eight hundred and forty-two plants were used, three distinct species and 13 varieties, four being pistillate and nine staminate.

Open and self-pollinations were made with the bisexual varieties to determine their fixity and stability as perfect flowered forms. Few showed any appreciable amount of sexual hybridity, the final figure being less than 3 percent. Open-pollinated imperfects (Cardinal, Haverland, Warfield) yielded progeny 45 percent of which was of a pistillate nature.

Self-pollinated perfect varieties (nine varieties and three separate species) produced over 90 percent of perfects in the first and over 99 percent in the second generation, Crosses between a unisexual, such as Warfield, and the bisexual varieties (Barrymore, Dickey, Gandy, Golden Gate) yielded in first generation progeny approximately equal numbers resembling either parent, in the second generation one imperfect to 106 perfect, and in the third, one to 27. Crosses of other imperfects (Haverland, Cardinal, Sample), with different perfect varieties afforded similar results.

Back-crosses were made between some of the progeny of these crosses and their perfect parents. In some cases the imperfects of the first generation were used and in other instances the perfects. When the perfects were used, about equal proportions of unisexual and bisexual forms were secured, as in the first generation of regular crosses; when, however, the perfects of the first generation were employed the ratio of perfects to imperfects was such as to recall the days of 1896—for it was 16 to 1.

These numerous breeding experiments have shown not only that dissociated sexes in the strawberry can be brought together, but also that a segregation of united sexes can be effected once the cross has been made. This, however, does not mean that it is possible to segregate the sexes of any or all perfect flowered plants, for that is determined by their genetic constitution.

The fundamental causes of sterility are deep seated and relate to the history of the plants, their ancestral forms and their genetic constitution. The three manifestations of sterility, namely, defective pollen, dichogamy and unisexuality, are expressions of inherited characteristics. The problem is phyletic. Its solution might tell how sterility came to be—how plants got that way. A knowledge of the *raison d'être* of sexuality among cultivated plants is to be sought in the structures and function of the ancestral forms. Hybridity is an undoubted cause and inheritance the connecting and preserving link.

The possibility of reestablishing the missing sex organs has been demonstrated experimentally. It is an accomplished fact. However, the question is, is it possible to do this without effecting other changes or introducing new characteristics which serve to modify the varietal type of the inbred form?

A study was made of the American varieties of strawberry with reference to inheritance of quality, shape, season of maturity, runner formation, color of flesh, flavor of berries, surface color of fruit and size of berries. These indicate a distribution of attributes among the progeny, in which there is a rather wide scattering of variety factors. This "splitting up" or segregation of separate factors furnishes additional evidence, if needed, of the hybrid nature of strawberry varieties.

However, certain results suggest the probable trend of inheritance. Some degree of blending occurred with respect to quality, yet some good quality offspring were derived from poor or fair quality parents.

There was much segregation in respect to shape of berry. For example, more than half of one lot of 24 varieties produced berries that were round-conic in shape like those of both parents, yet in four instances they were simply conic and in two were simply round.

The seven sets of crosses which were studied in reference to season of ripening showed a strong tendency toward intermediacy between the seasons of the parents.

The offspring fell into groups with respect to runner formation which were either like their parents or closely related, but never remotely related.

Five sets of crosses were made and four color groups constituted in the studies of color of flesh. The shades of flesh color in the offspring are much like those of the parents. Segregation and scattering into many classes occurred with respect to flavor. When, however, sweet and sour berries were crossed as nearly as might be equal numbers of progeny resembled each parent.

A comparative study was made of the sexually inbred progeny and the parent varieties as a corollary of the sterility experiment, in order to determine the merits and demerits of the new forms and to ascertain their ancestral resemblances.

The general effect of crossing Warfield, a pistillate, with the staminate varieties (Barrymore, Gandy, Dicky, Golden Gate) has been to delay the season of ripening by several days and slightly to modify certain unessential structures or qualities. The crosses were not violent but narrow and did not permit of great contrasts or offer much opportunity for segregation.

The crosses between Haverland, a pistillate, and the staminate sorts (Golden Gate, Marshall, Gandy, Dicky) gave new plants of excellent quality which showed a distinct persistence of the Haverland characteristics despite the sharp contrasts between the parents in several details of structure.

The progeny of Sample, a pistillate, and certain staminate varieties (Excelsior, Gandy, Longfellow) gave in the first instance forms that were like Excelsior in only two particulars, namely, medium size of berries and small size of calyx. There were no essential differences in the progeny of Sample and Gandy.

The crossing of early and late season varieties seemed to result in the production of midseason sorts. Although the flavor of berries among the varieties used had but a narrow range, yet the different acid qualities as recorded show intermediacy of flavor with a tendency toward the milder of the two degrees of acid quality of the parents.

In seed placement two types were observed; protruding as in Warfield, Gandy and Haverland, and depressed as in Excelsior, Barrymore, Golden Gate and Sample. When there was a contrast in the parent forms, the progeny showed segregation rather than intermediacy.

Core structures apparently did not exhibit any degree of consistency in inheritance.

These breeding trials indicate that it is possible to reestablish the missing sex without material and concomitant change of the inbred variety, provided the selected pollenizer possesses similar rather than unlike varietal characteristics.

## DISCUSSION OF THE STERILITY PROBLEM

### SEX IN STRAWBERRIES

A survey of sex in the cultivated varieties and among the wild species reveals what many growers recognize and what writers have announced, namely, that strawberry plants have many kinds and degrees of perfectness or imperfectness in sexual construction. There are, according to Richardson's (19) classification:

"1. Females with male organs undeveloped.
2. Females with most of the female organs atrophied or hypertrophied and inefficient, no male organs.
3. True hermaphrodites with both male and female organs undeveloped.
4. Males with the female organs undeveloped.
5. Males with the female organs only developed in a few flowers, generally the first flowers provided in each truss.
6. Flowers with neither organ developed, or with the female organs hypertrophied."

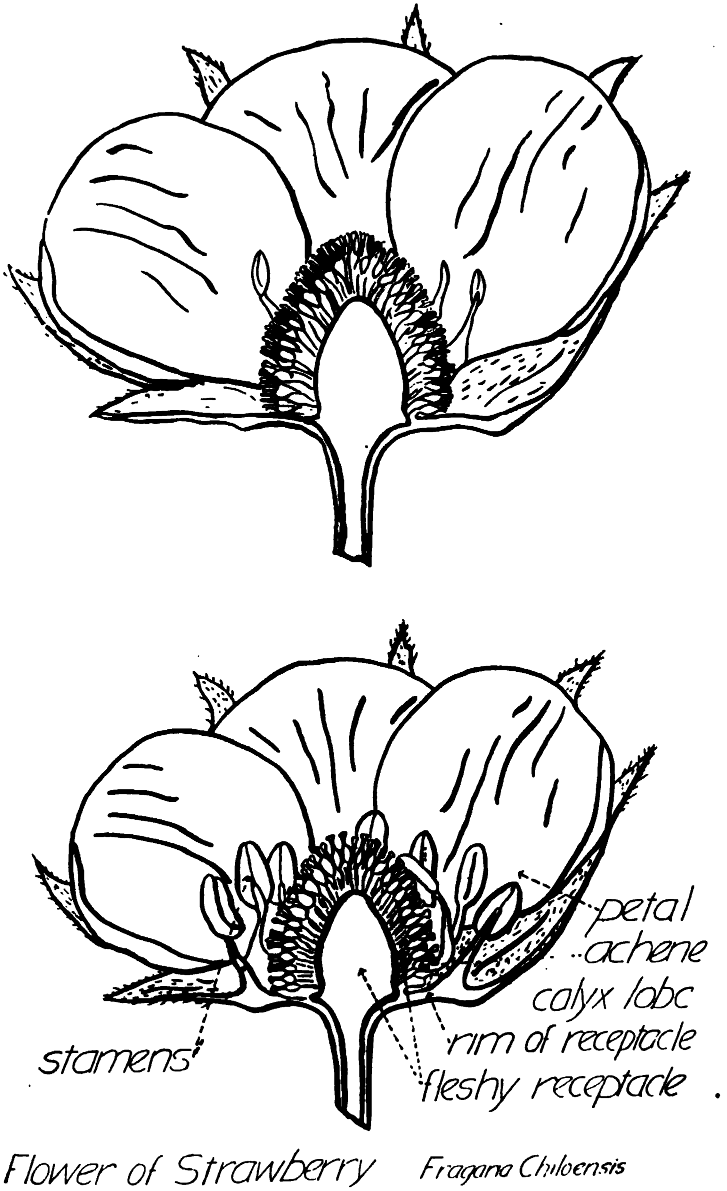
The writer has found all of these types except type 4 which he has never seen and has not been able to secure or produce. Such a type may exist, but if so it must be very rare. Moreover, type 3 as defined is rare, for generally hermaphrodites are well developed. It is common among growers to recognize only three forms of sexual construction, namely, perfect, imperfect and semi-perfect. These, with the exception of the semi-perfect ones, which are rather uncommon, occur in trade varieties in large numbers.

How we came to have these different forms and their significance in pomology are matters for discussion and investigation. It is not likely that all forms came into existence at the same time. One type probably antedates the others. One form is parental while others are offspring or variations. If the unisexual form was the ancestral one then the bisexual type has probably been produced by hybridization.

A study of sterility among strawberries represents simply one phase of the larger problem of sterility among cultivated fruits as a whole. The genus *Fragaria* was used for this purpose at this Station more particularly because of its convenient size and the short time required for new generations. The general problem of sterility is a broad one with many side lines. It is also a diverse one. It has many aspects and is related to many plants of widely different nature and structure. In general, the forms of sterility may be classified as those due to imperfection in structural arrangement of blossoms; to unequal maturity of the sexes; to unfruitful habit of growth; to natural impotency of pollen; to the use in propagation work of partial or completely sterile buds, grafts, or stolons; and to inheritance, or transmission of sexual defects. This latter cause—inheritance or transmission of sexual defects—is the one stressed in this bulletin.

## FRAGARIA A VARIABLE GENUS

The genus *Fragaria* is a most flexible and unstable group of plants, and there are many variable forms within it. Deviations from the normal type may be either structural or functional, the one being as common as the other and both being often seen in conjunction. Botanists do not agree as to the exact limits of a species, some recognizing more forms than others. Several sub-species can be made of the group *Fragaria,* as is noted herewith. *Fragaria monophylla* has but one leaf; *F. virginiana* often divides at the crown; *F. vesca* as an alpine form may produce white berries; *F. chiloensis* produces innumerable runners and behaves differently, both sexually and productively, in different climates and soils. There is also a runnerless variety, *F. eflagella,* which is said to be unable to form runners, while *F. elatior* excells in its ability to produce runners. Species *elatior, chiloensis,* and *virginiana* show different degrees and manners of abortiveness. as do many cultivated varieties derived from these species. The form *F. collina* is classed as dwarf under normal conditions either in the wild or under cultivation. Some forms of *F. collina* are further distinguished and designated as variety *abortiva,* because of their sterile



**Pistillate (upper) and staminate (lower) flower types; the former showing traces of defective stamens and pollenless anthers. The lower figure illustrates a perfect staminate flower.**

nature. The anthers are large but carry no pollen. White forms of *F. vesca* and *virginiana* are not uncommon in America. The Pan-American, progenitor of the race of North American everbearing strawberries, possesses the everbearing habit to such a marked degree that it seems to have lost its capacity for runner formation and is, therefore, propagated only by division of the crown. Again the Bush Alpine strawberry forms no runners and must be propagated by seeds. The ability of the everbearing sorts to product flowering stems from the axils of some leaves from the main stem represents another departure from the original *Fragaria* type, and serves incidentally to differentiate the everbearing forms from the "one season" crop plants. Moreover, variations or varieties within the species occur almost without number; some as chance seedlings, others resulting from definite crosses, still others reverting to primitive forms, and, finally, we have the fall bearing varieties, originating from adventitious buds at the base of old leaves. Many of these deviations from the norm, perhaps all of them, may be attributed to recent or latent hybridity, to some method of propagation or to the peculiarity of environment. Jeffry (15) believes there is general genetic impurity among all Rosaceae, of which family Fragaria is a member. If this supposition is correct, the sterility problem embraces a most important group of economic plants.

The problem as discussed in this bulletin is that of the missing sex, how it came to be missing, and how to deal with the situation created by its loss. The approach is from three points of view:

1. The influence of environment on the sex of plants, as shown in nutritional trials.
2. The history of varieties and the sexual nature of ancestral species and varieties in regard to their relation to cultivated varieties.
3. The inheritance and transmission of sex as shown in breeding experiments.

## SEXUALITY AND ENVIRONMENT

### STERILITY OBSERVATIONS AND NUTRITION TRIALS

It is suggested in the literature of strawberry culture that external conditions are somewhat influential in determining the sex of strawberries. For instance, Thomas (23) states that the variety Crescent, which is generally imperfect, sometimes produces a few stamens under conditions of rich culture. Stirling Castle is reported by Castle (5) as being self-fertile in England but, when transferred to the United States, as becoming self-sterile. Keens' Seedling is said by Darwin

(7) to be perfect in England and imperfect in America. Fletcher (10) reports that Crescent, like some other pistillates, may at times produce enough pollen for crossing. Again, the Royal Hautbois has been assumed to be of the same nature, for it is said to be fertile in the warm soils of Surry and Kent, while on the cold soils of Bedfordshire it is found to be infertile on account of the apparent suppression of stamens. Another and more rational explanation, however, has been given for the strange behavior of this variety by Darwin (7), who states that the true Hautbois (*F. elatior*) properly bears male and female organs on separate plants that, consequently, the species has been designated *dioecia* and that it frequently produces hermaphrodites. By propagating these latter forms and destroying others, Lindley has succeeded in establishing a prolific race of perfect flowered plants. Darwin also records his observation to the effect that when strawberries are forced in hothouses the varieties are more apt to be imperfect than when grown under garden conditions. This dual behavior as to sex is not peculiar to strawberries, for sterility is not a constant factor. It has been observed that pears, cherries and apples are variable in their degree of infertility in different sections of the country.

In discussing sex in fruit, Bailey (2) calls attention to the tendency to unisexuality and suggests that it must be a general trend toward dichogamy. This writer states that increased amelioration of fruit imposes a severe tax upon plant energies, and to meet this condition plants must of necessity economize. The result seems to be a sexual defect resulting in impotency of pollen and elimination of one sex. Bailey further expresses the opinion that sterility is hastened by high cultivation.

Wray (25) states that all hermaphrodite strawberry plants appear to become more or less imperfect as they get older, until in some cases they fail to bear a single perfect berry. Even the very best hermaphrodites in the course of a few years exhibit this inherent tendency to become infertile. Observations in Alaska by Georgeson (11) are to the effect that environment has much to do with sex and fertility, since wild forms of *F. chiloensis* may be found that are staminate and sterile, as well as pistillate. The plants luxuriate along the beaches, yet in good soil produce no fruit whatsoever because of the formation of innumerable runners. Fruitage occurs in Alaska only when the plants are grown in poor and somewhat sterile soil.

Pritchard (18) and Schaffner (21) show that there is considerable variation in the sexual expression of hemp under certain environmental conditions; and V. R. Gardner, in an unpublished study on the nutrition of the strawberry, reports that the Dunlap variety exhibits some instability of sexual construction under different conditions of food supply.

The preceding citations of the dual behavior of strawberries as regards sex and sterility seem to be in harmony with the results set forth in numerous reports touching the inconstancy of fertility of many orchard fruits. For instance, the Yellow Newton, Rhode Island Greening and Grimes Golden apples have repeatedly been listed as self-sterile in one place and self-fertile in another. The Bartlett pear is reported as self-fertile in New Mexico, whereas elsewhere in this country it is reported as largely if not wholly self-sterile. Sweet cherries also show variation in degrees of sterility in different sections and modification as to intersterility. These cases point clearly to the fact that sterility is not a constant factor among fruit plants.

Schaffner (21), as a result of his studies, advances the following interesting ideas which are pertinent to the study of the sterility problem:

"In its simplest form it (sexuality) is a physiological difference expressed only in the developing sexual cells. . . . . . . . . . In at least the vast majority of cases, and probably in all, the sexual condition is simply a state of the living substance which may continue for a greater or less length of time before a neutral state or the opposite sex condition is set up. . . . . . . . . .

"Sex appears in some way to be associated with physiological and chemical states of the living protoplasm. It is perhaps most reasonable to assume, at present, that a certain organization or complexity of the cell is necessary before sexual states originate. But it is not true, on the other hand, that these states are necessarily set up at any stage of the life history even in organisms that have the essential complexity. . . . . . . . . .

"In the higher plants the reduction of chomosomes has nothing to do with the maleness or femaleness of the gametophyte. The determination of the sex takes place in the vegetative tissues of the sporophyte. Whatever it is that determines that the given tissue shall develop as a megasporophyll or a microspoporphyll also determines absolutely the sex of the following generation of gametophytes."

## VERMONT TRIALS: SOIL, FOOD, SEX

In view of the results secured by others and cited above, indicating the probable effect of soil fertility on the sex nature of strawberry plants, it seemed desirable to pursue this line of investigation in connection with the studies in hand. For this purpose a lot of small plants taken as offsets were employed. The variety used was Crescent (pistillate) which is often reported as producing some pollen under certain cultural conditions, possibly enough for the self-pollination of some of its flowers.

A fertilizer mixture carrying 4 percent nitrogen, 7 percent available phosphoric acid, and 8 percent potash was applied at rates ranging from 500 to 4,000 pounds per acre. The plants were grown in pots, the amount of fertilizer for each lot being prepared in advance of potting. Furthermore, soils of different types and fertility values (clay, clay loam, potting soil, sandy loam, sand, and greenhouse loam) were used. Table I sets forth the outcome of these trials.

TABLE I.—RELATION OF SOIL AND FERTILIZER TO BLOSSOM PRODUCTION

CRESCENT STRAWBERRIES, ALL BLOSSOMS PISTILLATE

**Influence of Soil on Blossom Production**

| Nature of soil | 1-year old plants | | 2-year old plants | | 3-year old plants | | Average average per plant |
|---|---|---|---|---|---|---|---|
| | Number of plants | Average number of blossoms per plant | Number of plants | Average number of blossoms per plant | Number of plants | Average number of blossoms per plant | |
| Clay | 24 | 37 | 24 | 41 | 19 | 16 | 31 |
| Clay loam | 24 | 37 | 24 | 79 | 17 | 33 | 50 |
| Potting soil | 24 | 45 | 24 | 86 | 22 | 37 | 56 |
| Sandy loam | 24 | 45 | 24 | 71 | 24 | 33 | 50 |
| Sand | 24 | 9 | 24 | 42 | 23 | 10 | 20 |
| All treatments | 120 | 35 | 120 | 64 | 105 | 26 | 42 |

**Influence of Fertilization on Blossom Production**

**(4-7-8 mixture, plants in pots)**

| Rate of application Pounds per acre | 1-year old plants | | 2-year old plants | | 3-year old plants | | Average average per plant |
|---|---|---|---|---|---|---|---|
| | Number of plants | Average number of blossoms per plant | Number of plants | Average number of blossoms per plant | Number of plants | Average number of blossoms per plant | |
| 500 | 6 | 76 | 46 | 81 | 6 | 43 | 67 |
| 1,000 | 6 | 70 | 46 | 93 | 6 | 26 | 63 |
| 1,500 | 6 | 54 | 46 | 90 | 6 | 37 | 60 |
| 2,000 | 6 | 77 | 46 | 79 | 6 | 58 | 71 |
| 2,500 | 6 | 55 | 24 | 57 | 6 | 23 | 45 |
| 3,000 | 6 | 68 | 21 | 90 | 6 | 30 | 63 |
| 3,500 | 6 | 51 | 24 | 53 | 6 | 30 | 45 |
| 4,000 | 6 | 53 | 22 | 56 | 6 | 29 | 46 |
| All treatments | 48 | 63 | 275 | 75 | 48 | 35 | 58 |

Neither modification of soil texture or character nor of fertilizer application altered the sexual construction of the plants. The nature of the soil was effective only in changing the number of the blossoms. Extremes in soil texture, namely, clay and sand, reduced the number of blossoms, while commercial fertilizers used at different strengths stimulated neither stamen nor pollen production. With but a single exception, sand, the average numbers of blossoms were in the following order and ratio: 2-year old, 100; 1-year old, 70; 3-year old, 44.

*Effect of Nitrate.*—Nitrate of soda was applied dissolved in water in order to determine its possible effect on the sexual development. It was first applied on small plants, just large enough to be well rooted, about three months before the time they were due to blossom. Weekly applications were made by dissolving a given weight in a definite volume, two strengths being used, 0.1 and 0.2 percent concentration. Several plants were watered with dissolved nitrate, each specimen receiving 125 c. c. weekly for 12 weeks. Two varieties were used—Glen Mary, a semi-perfect, and Crescent, an imperfect. Many more blossoms were produced on the fertilized than on the check plants but the sexual structures remained unchanged.

*Effect of Carbon Dioxid.*[1]—If nutrient supply can affect the sexual nature of a plant, it well may be that that derived from the air may be as effective as that derived from the soil. Carbon dioxid was supplied

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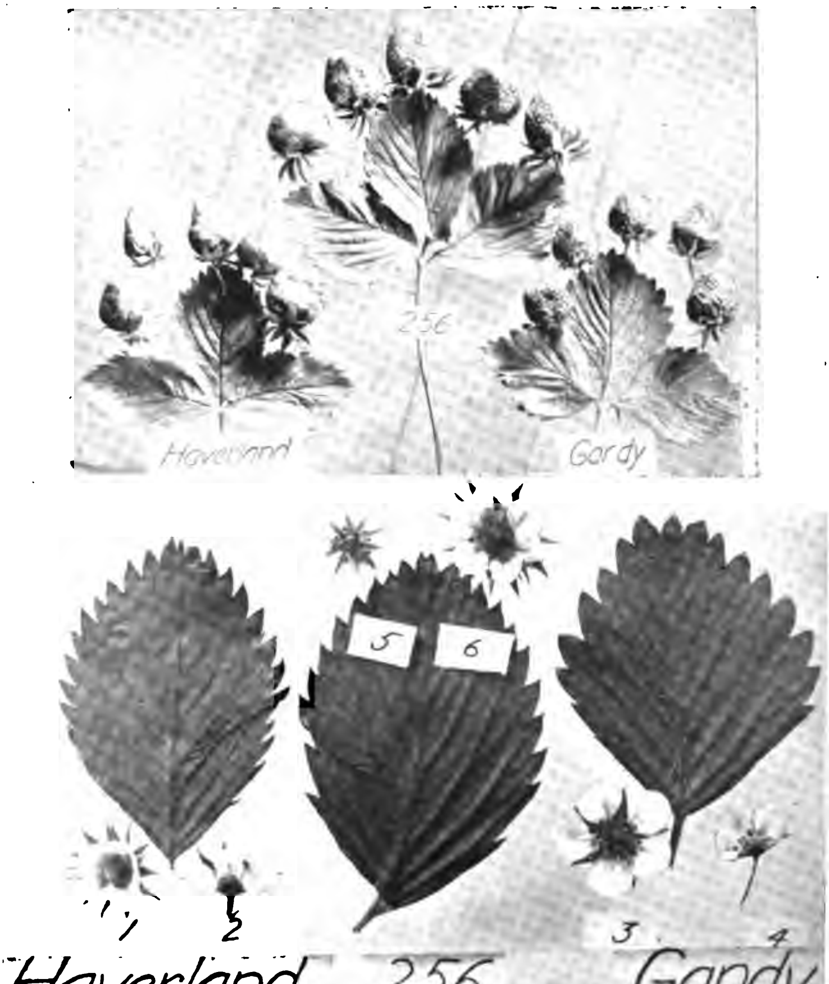
[1] See Vt. Sta. Bul. 211, pp. 44-45 (1918).



Haverland P and Gandy S, showing in fruit and leaf above; parent characteristics in leaf and blossom below; and the product of the cross—No. 256—in the middle in both cases. The cross resulted in larger berries, in segregated blossoms, and in intermediate leaf margin characters.

to semi-perfect strawberry plants from a gas generating apparatus, the carbon dioxid being liberated about the foliage. The Glen Mary, a weak pollen producing variety, was used. The plants were submitted to the usual pre-forcing treatment, were refreshed for a week and then divided into two groups, treated and check. The gas-treated lot was dosed for 185 days (November 17, 1915-May 19, 1916), during which time 400 grams sodium bicarbonate and equivalent amounts of sulphuric acid were used daily and 116 liters of carbon dioxid evolved. The plants were grown in uncovered glass boxes measuring 52 x 28 x 12 inches. They began to blossom February 4, from which date notes on flower structure were recorded. The results of the test are shown below:

TABLE II.—INFLUENCE OF CARBON DIOXID ON STAMEN PRODUCTION

| Treatment | Number of plants | Average number of blossoms per plant | Average number of stamens per blossom |
|---|---|---|---|
| $CO_2$ .......... | 15 | 40.6 | 30.4 |
| Untreated .... | 15 | 27.7 | 29.3 |

The treated plants produced on the average 13 more blossoms per plant than did the untreated ones, but neither was the average number of stamens per blossom nor their pollen content increased. The Glen Mary variety is semi-perfect. Stamen and pollen production during the early part of the blossoming period is scant or nil and at best it is insufficient later on. Neither the earliness nor the lateness of stamen or pollen production was affected by carbon dioxid dosage.

It was thought that possibly carbon dioxid dosage might favorably affect the offspring of the treated plants. In order to determine this matter it became necessary to secure fruits from treated plants, to grow seedlings from them and to continue the treatment on the new generation. A number of self-fertilized fruits was secured from which new plants were grown and treated as were their parents, the seedlings being dosed with gas before the flower buds had formed. In all respects the results were similar to those secured with the first generation. The number of flowers was somewhat increased but neither the sexuality nor the fertility was preceptibly modified.

The effect of carbon dioxid dosage on unisexual varieties, like the Crescent, was also tested. No material change was wrought in these imperfect forms. No intermediate stages of sexual development were secured.

The experimental results secured by others and heretofore cited (pages 12-14) as to the presumed influence of environment in modifying the sex of plants to the contrary notwithstanding, in view of the nutritional trials reported herewith (pages 15-17) and in recognition of breeding experiments reported elsewhere (pages 21-27), the writers deem it very unlikely that nutritional factors can furnish a basis for the mechanism of sex determination. If, however, the determining factors hang in the balance, the plane of nutrition, be it balanced or unbalanced, sufficient or insufficient, conceivably might exert some influence. However, the germinal basis for sexual dimorphism and unisexuality can scarcely be attributed to the nature or the extent of the food supply.

### UNISEXUALITY ANTEDATES CULTIVATION

Pistillate varieties antedate the beginning of the cultivation of the strawberry plant. Pistillate forms were recognized among the native species of North and South America. In the Bailey revision of Gray's Field, Forest and Garden Botany (12), the following species were classed as more or less dioecious: *F. vesca,* Lin., from Europe; *F. moschata* Duch.; the Hautbois from Europe, *F. elatior; F. virginiana,* Duch., the wild strawberry of the United States; *F. chiloensis,* Duch., the garden strawberry from Chile, which is one of the accepted parents of the cultivated varieties of the present time. The only other species recognized by this authority is *F. indica,* Ands., the Indian strawberry, which is perfect in its sexual parts.

The introduction of the Chilean strawberry into Europe was due to a French officer, Frezier—as cited by Bunyard (4). Frezier found this strawberry both wild and cultivated, during his travels in 1776, and its large size induced him to attempt its introduction into Europe. The long journey from Chile to France and the scarcity of fresh water made the importation of the plants a matter of some difficulty and only five specimens survived. One of these was planted near Brest and became the parent of the strawberry industry carried on in that district. The surviving quintet all happened to the "the females of the species," hence for a time no fruit was secured because of the lack of pollenizers. Fruit was only produced when the immigrants were supplied with pollen from one of the other species then growing in France. *F. chiloensis* is found wild in Chile and in Alaska and on the Pacific Coast region of North America. Clausen (6) writes that this species occurs in California and was used by Etter in breeding the Ettersburg strawberries which are known locally as "sand" or "beach" strawberry. The Chilean parentage, in part, of our cultivated strawberries was established by Bailey and from these findings it seems likely that Elton's Seedling, Keens' Seedling, and other pistillate varieties of those early days inherited this imperfect character from their Chilean ancestor. It is likely also that Hovey and Haverland, which show this same sexual imperfection, inherited it from the Chilean species. Still more recently, Fletcher (8) has traced the ancestry of the cultivated strawberry and finds evidence of *F. virginiana* heritage among the descendants. Even so, its seems that modern pistillate varieties have inherited their imperfections from uncultivated pistillate forms of either *F. virginiana* or *F. chiloensis* or both, for both were evidently more or less unisexual in the early days as they are now.

F. VIRGINIANA
(Courtesy of the Macmillan Co.)

It has been reported that the Chilean form did not vary materially under cultivation. Even one hundred years after it was introduced there were only a few well recognized varieties. *F. vesca* is also believed to have been very unprolific in giving rise to varieties. Moreover, it has been our experience at this Station that the native strawberry when grown in the greenhouse responds but slightly to cultural conditions, except when it has been hybridized.

It does not appear that strawberries "run out" although there is current opinion to this effect. It is more correct to say that varieties disappear from the trade and are supplemented by new sorts. However, the reason for such disappearance is not deterioration, but, rather, a desire to eliminate old varieties and to create a demand for new ones. In other words, trade exigencies are apt to furnish the impelling reason. It is characteristic of human nature to chase after strange gods, to welcome new things, to essay the unknown; and the nursery trade is not the only one to capitalize this trait.

To controvert the idea that varieties run out one may cite three cases: The red-fruited Chilean has been grown in the highlands of Peru since 1557, for nearly four centuries, and it does not appear to have deteriorated. The Large Early Scarlet retained its prominence in western New York for nearly 75 years. It is extremely doubtful if any current variety can hold undisputed sway for over 20 years, as did the Wilson. Those varieties that have been produced by hybridization may change their character or "run out" as a result of the acquisition of new attributes, which really, in a way, make them into different sorts. Hybridization seems a likely factor—perhaps the sole one—in accounting for either unsexuality or bisexuality among strawberries.

F. CHILOENSIS
(Courtesy of the Macmillan Co.)

## BREEDING WORK ELSEWHERE

### STERILITY STUDIES

The sterility of fruit plants has been the subject of serious attention among pomologists for some years, but very little study has been given to the strawberry until recently. Scarcely any attempts have been made toward reestablishing the missing or non-functional sex. A few of the more direct contributions to our knowledge of strawberry sterility deserve attention in connection with the survey of the results secured in the present investigations. No attempt is made to review the literature on general sterility, but only such as is pertinent to the problem of sterility among strawberries.

Valleau (24) found various degrees of pollen abortion due, he believed, to the production of staminoda which rarely develop as far as the pollen mother-cell stage, and cites as a cause for such lack of development a condition due to improper chromosome combination. He states that many varieties are heterozygous for certain factors. Valleau seems inclined to accept the idea that hermaphrodites have been derived from staminates of the wild dioecious forms.

In an incomplete study of inheritance of sex in strawberries, Anthony (1) found that when imperfects were pollinated with perfects, nearly half of the offspring were like one parent and the rest like the other; that when perfects were pollinated with perfects, with some exceptions, the progeny were nearly all perfect; and that among the crosses in which Prolific, Sharpless, Fort, Marshall, and Quality were used, the results were irregular and abnormal. These latter cases, however, as their ancestry seems to indicate, may be due to parental impurity.

In a preliminary account of his studies of sex, Richardson (19), reported that he had difficulty in securing pure males in the crosses of *F. chiloensis* and *F. virginiana,* and in selfing hermaphrodites, predicted, but did not prove, that most characteristics in these species can be segregated.

In noting the sex nature of offspring from open pollinated strawberries, Macoun's (17) published statements indicate that sometimes the staminate and sometimes the pistillate character predominates. For instance, the progeny of Wm. Belt gave Hermia, which has perfect flowers, and Portia, Viola and Virgilia, which have imperfect ones. The seedlings from Bubach, which of itself is imperfect, gave Cordelia, Lucetta, Mariana and Miranda, which were all bisexual, but also Cassandra, Desdemona and Julia, which were unisexual. The male parent in all these cases was unknown for the blossoms were open pollinated. It is possible that in some of these cases one parent was prepotent over the other, yet Macoun preferred the opinion that the sex of the offspring is a matter of inheritance. Among the early records of Fuller, cited by Hedrick (14) it was noted that "in growing seedlings from pistillate strawberries not more than one in ten retained the pistillate character." Keffer (16) made notes on the character of seedlings of some imperfect varieties of strawberries as follows: Warfield 2nd, a pistillate variety, gave rise to 814 seedlings, of which 290 were perfect and 524 pistillate; Lady Rusk, a pistillate, gave 822 seedlings, of which 383 were perfect and 499 imperfect; Crescent, which is pistillate, gave 2,044 seedlings, of which 853 were perfect and 1,191 imperfect; Bubach 5, gave 394 seedlings, of which 188 were perfect and 206 imperfect; Gandy, a perfect form but a weak pollen producer, gave 166 seedlings, of which 104 were perfect and 62 imperfect. These records indicate that the sex nature of seedlings shows a tendency to follow that of the mother plant. It is presumed that at least one parent in each case was perfect, not merely staminate, and in the last instance both may have been more or less perfect flowered.

## PARENTAGE OF PISTILLATE VARIETIES

A review of the literature of strawberry varieties affords interesting evidence of the probable origin of pistillate varieties. The most recent and authentic history of varieties has been set forth by Fletcher (9), whose list embraces 1,879 varieties originating in North America. From this list it has been possible to trace the ancestry of many varieties of pistillate strawberries. Only 402, or less than one-fourth the total number were pistillates. In 81 instances, where the varietal history is complete, pistillate ancestry can be proven.

One of the immediate parents of the following 62 varieties was pistillate:

Anna Kennedy
Arrow
Auburn
Berlin
Bessie
Big Bob
Bird
Black Prince
Bush Cluster
Dora
Early Harvest
Elma
Enormous
Fleming
Goldsborough
Haverland
Hazel
Heath
Methven Scarlet
Mrs. Fisher
Nettie
Ona
Oriole
Paul Jones
Peak's Emperor
Productive
Purdue

Buster
Cardinal
Carrie
Carrie Silvers
Cassandra
Cloud
Collingwood
Colonel Cheney
Columbia
Columbus
Cornucopia
DeWet
Ham
Itasca
July
Latest
Lehigh
Lida
Longfield
Louis Hubach
Lyon
Magnate
Mele
Mellie Hubach
Reba
Red Prolific
Rival Hudson
Shuster
Steven's Early
Stone
Tom Walker
Velvet
Warfield
Westbrook
Windsor.

One of the grandparents of the following 15 varieties was pistillate:

Backett's Prolific
Banquet
Black Beauty
Burr's New Pine
Daisy
Frances Cleveland
Gold
Green Prolific
Hovey
Ionia
Malvina
Monroe Scarlet
Mote's Seedling
Mottier's Seedling
Moyamensing

One of the great-grandparents of the following four varieties was pistillate:

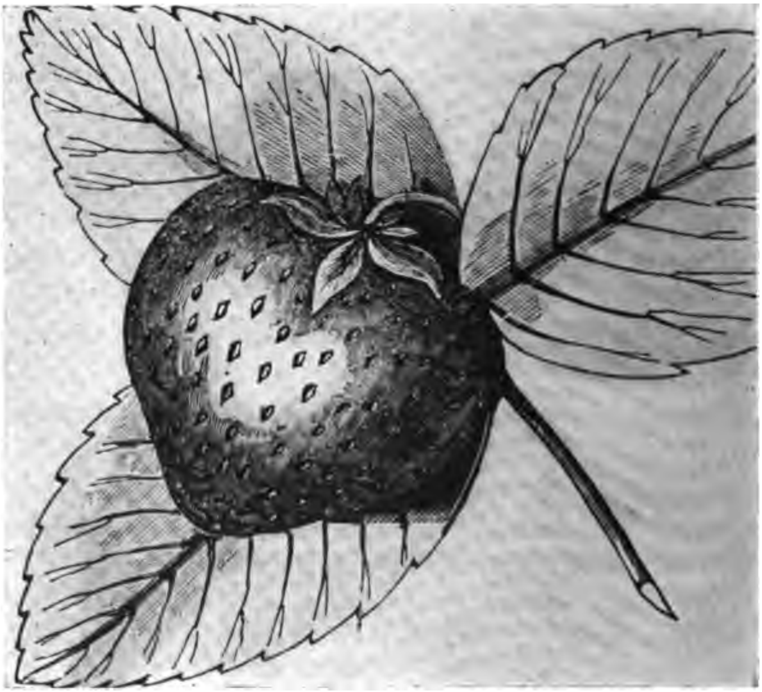
Edgar Queen
General Putnam
Huddleston's Favorite
Shephard

The only pistillate varieties among the 402 which apparently do not possess pistillage ancestry, were Dunmore and Lady of the Lake, but since their early history is somewhat obscure these exceptions may not be real ones. Nothing can be stated as to the remaining 319 pistillate varieties listed by Fletcher, since their origin is not definitely known.

The variety Hovey which was introduced into America in 1834 and was one of the early varieties of a pistillate nature, is held by some to have been the predecessor of all our commercial sorts. Bailey once wrote that he thought all the early-day varieties came directly from the Chilean species, which has always been more or less dioecious.

Among the fall, or everbearing, varieties which are mostly of recent development, the segregation of sexes appears. For instance, Productive and Autumn are imperfect, while Superb and Progressive are perfect. Autumn was produced from seeds of Pan-American, which in turn was from a seedling plant known as Bismarck. Francis and Americus, two perfect varieties, were produced by crossing Pan-American and Louis Gauthier.

When the prolific character of certain pistillate varieties of the early days is considered it is easy to understand the rapid appearance of the unisexual forms. For instance, there are 51 varieties of the lineage of Hovey, 41 of the Wilson, 69 of the Sharpless, and 63 of the Crescent, all varieties of much prominence in strawberry history. It is significant that so many pistillate varieties show not merely a possible but a probable ancestral origin of their pistillate nature.

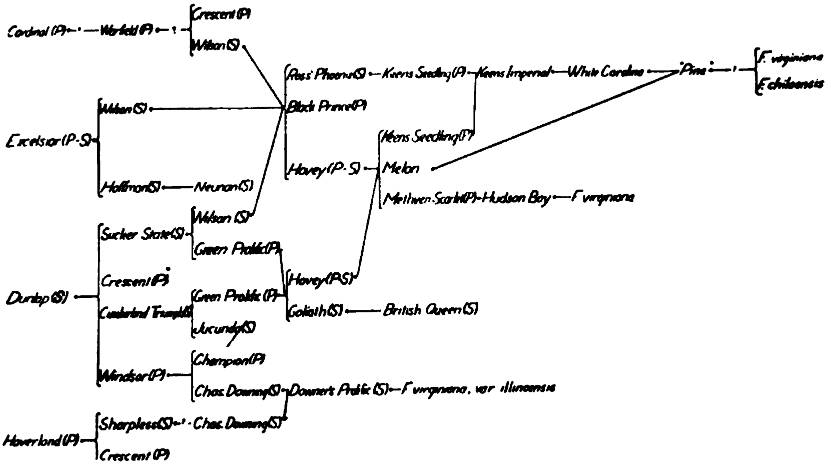


HOVEY
(Courtesy of Va. Exp. Sta.)

There is some difference of opinion as to which sex type—staminate and bisexual, or pistillate and unisexual—is the more primitive form, a point which may never be settled by proof and may not be of importance; but even so, one may say that if the bisexual type is the more primitive one, then the unisexual form is a later descendant, the product of a cross, and has appeared as the persistent sex of a once perfect flowered strawberry plant. Or, otherwise, if the unisexual type antedates the bisexual, then the latter is a hybrid produced by a cross with a unisexual.

## LINEAGE OF FOUR VARIETIES

The probable genealogy of four varieties of strawberry has been worked out at this Station and is displayed diagrammatically herewith.



Lineage of four varieties, indicating derivation of pistillates and staminates and the intermediate forms, from their probable ancestral species.

The Chilean and Virginian species are there shown as the progenitors of the cultivated berries of the United States. Among the four varieties selected to illustrate the lineal descent were two pistillate sort—Cardinal and Haverland, one perfect or bisexual—Dunlap, and one semi-perfect—Excelsior.

The Cardinal came from the Warfield which was also pistillate and was the product of a cross between Crescent which is pistillate and Wilson which is staminate. The mixed ancestral derivation of the Wilson is shown, namely: Hovey, Black Prince and Ross Phœnix; the first of this trio being semi-perfect, often recorded as pistillate to staminate, the second pistillate; and the third staminate. Since the origin of Black Prince is unknown, the further lineal history of Cardinal is restricted either to Ross' Phœnix, thence to Keens' Seedling, Keens' Imperial, White Carolina, and to the Pines, or to Hovey, which is reported to have arisen from Keens' Seedling crossed with either Melon or Methven Scarlet. Since both Keens' Seedling and Melon come from the Pines it is quite certain that the line of descent of Hovey also traces directly back to the Pines. If, however, Methven Scarlet was one of the parents of Hovey, it would appear that there was an introduction of still more of the *virginiana* strain into the make-up of Hovey. In any case the "Pine," which is believed to be the result of a cross between *F. chiloensis* and *F. virginiana,* was at least one of the progenitors of the Cardinal.

It is thus seen that the pistillate character of Cardinal can be traced back through at least four ancestral varieties and that where crosses occurred at least one parent was known to be pistillate. A number of prominent varieties were in this ancestral line, a fact which accentuates the importance of tracing this genealogy since Cardinal was one of the varieties used in the Vermont breeding experiments.

**KEENS' SEEDLING**
(Courtesy of the Macmillan Co.)

The origin of Haverland, another pistillate variety, is of interest. Haverland is the product of a cross between Sharpless, a staminate and Crescent, a pistillate. Sharpless came supposedly from Charles Downing, which in turn came from Downer's Prolific, which was a seedling variation of a native Illinois plant, known as *F. illinoensis,* a variety of *F. virginiana,* a dioecious species. The origin of Crescent is not known, although it is the pistillate parent of Warfield, thus being only two generations removed from Cardinal.

The genealogy of Excelsior was also traced. Its immediate parents were Wilson and Hoffman, both of which were staminate. The Hoffman line stops with Neunan which was also staminate; but the Wilson line embraces the trio, Ross' Phœnix, Black Prince and Hovey, the latter being semi-perfect, as is also Excelsior. It is thus seen that Excelsior has much the same lineage as has been followed out for Cardinal.

The bisexual character of the Dunlap can be traced back through several generations of bisexual parent varieties. It is probable that either Sucker State or Cumberland Triumph was the male parent of Dunlap. In either case the line of descent goes back to the varieties which resulted from the cross between *F. virginiana* and *F. chiloensis.* Despite the fact that there was a pistillate variety as one parent in some of the crosses, there seems to be an unbroken line of bisexuals all the way on the male side; and since the Chilean and Virginian ancestors were more or less dioecious—some males, some females and some bisexuals—the connection between these ancestral species and the present day varieties seems quite probable. The fact that some were produced laterally on the line from the Pines to the Dunlap, for instance, is believed to be due to the linkage of factors, in one case for unisexuality and in the other for bisexuality, thus yielding "pure" pistillate and "pure" staminate varieties.

## POLLINATION TRIALS AT THIS STATION

The preceding brief review of literature, together with citations of limited trials by several investigators, clearly indicate the need of further and more extensive experimental work; hence the breeding trials reported herewith.

Twelve varieties were grown under conditions affording open-pollination. Considerable numbers set fruit. Plants were raised from these open-pollinated fruits and in due time their floral structures were observed and recorded.

There were five perfect flowered varieties (Barrymore, Gandy, Golden Gate, Longfellow, Marshall) which yielded 940 plants of which 927 or 98.6 percent were perfect like the mother plant. There were three imperfect varieties (Cardinal, Haverland, Warfield) which yielded 557 plants, 305 of which were perfect, resembling some unknown paternal parents and 250 imperfect like their maternal parent, thus manifesting a segregation of sexes in slightly unequal numbers, 44.9 percent being like the mother plant.

Glen Mary, a semi-perfect variety, set seed enough to yield 290 plants, 262 of which were perfect, 23 imperfect and five semi-perfect.

Among the exotic varieties or species, there were 151 Hautbois and 37 Chilean plants under trial for open-pollination records. These yielded 188 plants, all of which were perfect as were the particular parents from which they were grown.

By combining all data from these first generation trials, there were found to be 1,975 plants in all, 1,682 of which were perfect, 286 imperfect, and seven semi-perfect. The adjoining table gives the data for the several varieties in each group.

### TABLE III.—OPEN-POLLINATED PLANTS

SEX OF PROGENY—FIRST GENERATION

| Parent | | Number of progeny | | | | |
|---|---|---|---|---|---|---|
| Nature | Variety | Total | Perfect | Imperfect | Semi-perfect | Percentage like mother |
| Perfect | Barrymore | 47 | 47 | 0 | .. | 100.0 |
| | Gandy | 224 | 218 | 6 | .. | 97.3 |
| | Golden Gate | 349 | 345 | 4 | .. | 98.9 |
| | Longfellow | 171 | 170 | 1 | .. | 99.4 |
| | Marshall | 149 | 147 | 2 | .. | 98.7 |
| | Total | 940 | 927 | 13 | .. | 98.6 |
| Imperfect | Cardinal | 184 | 50 | 134 | .. | 72.8 |
| | Haverland | 191 | 112 | 77 | 2 | 40.3 |
| | Warfield | 182 | 143 | 39 | .. | 21.4 |
| | Total | 557 | 305 | 250 | 2 | 44.9 |
| Semi-perfect | Glen Mary | 290 | 262 | 23 | 5 | 1.7 |
| Exotic | Hautbois | 151 | 151 | 0 | .. | 100.0 |
| | Chilean | 37 | 37 | 0 | .. | 100.0 |
| | Total | 188 | 188 | 0 | .. | 100.0 |
| All plants | Perfect | 940 | 927 | 13 | .. | 98.6 |
| | Imperfect | 557 | 305 | 250 | 2 | 44.9 |
| | Semi-perfect | 290 | 262 | 23 | 5 | 1.7 |
| | Exotic | 188 | 188 | 0 | .. | 100.0 |
| | Total | 1,975 | 1,682 | 286 | 7 | .... |

The open-pollination trials were continued for a second generation but with fewer varieties. The data are shown in table IV. Gandy and Golden (perfects) combined gave 188 plants, all of which were perfect. Gandy was continued to a third generation in which there were 15 plants, all of which were perfect. Glen Mary (semi-perfect) gave a total of 27 plants, all of which were perfect, and the Hautbois 39 plants, all of which were likewise perfect.

TABLE IV.—OPEN-POLLINATED PLANTS

SEX OF PROGENY—SECOND GENERATION

| Parent | | Number of progeny | | | | Percentage like grandmother |
|---|---|---|---|---|---|---|
| Nature | Variety | Total | Perfect | Imperfect | Semi-perfect | |
| Perfect | Gandy | 157 | 157 | 0 | 0 | 100 |
| | Golden Gate | 31 | 31 | 0 | 0 | 100 |
| | Total | 188 | 188 | 0 | 0 | 100 |
| Semi-perfect | Glen Mary | 27 | 27 | 0 | 0 | 0 |
| Exotic | Hautbois | 39 | 39 | 0 | 0 | 100 |
| All plants | Perfect | 188 | 188 | 0 | 0 | 100 |
| | Semi-perfect | 27 | 27 | 0 | 0 | 0 |
| | Exotic | 39 | 39 | 0 | 0 | 100 |
| | Total | 254 | 254 | 0 | 0 | ... |

The sex behavior of certain open-pollinated native strawberries, *F. virginiana,* was also ascertained. A considerable number of wild berries were gathered and 572 plants raised. In due time the blossom data were collected and the proportional numbers of unisexual and bisexual plants recorded, 276 being perfect flowered and 296 imperfect. Although the exact sexual status of the plants from which the berries came was not ascertained, many of them, perhaps half, were imperfect.

In the abstract the preceding data are of little value, but when considered in the light afforded by other results, they seem to suggest some degree of connection between the sex nature of the parent and of the offspring among strawberry plants.

### SELF-POLLINATION TRIALS

To what extent are the bisexual varieties true hermaphrodites? Are they fixed and stable in this respect? An answer to this question was obviously imperative at the outset of our trials.

The subjoined table shows the results of the first generation following self-pollination of nine cultivated varieties, of one exotic and of two native species.

TABLE V.—FIRST GENERATION OF SELF-POLLINATED PERFECT VARIETIES

| | | Number of progeny | | | |
|---|---|---|---|---|---|
| Parent | Total | Perfect | Imperfect | Semi-perfect | Percentage perfect |
| Barrymore ....... | 656 | 602 | 54 | .. | 91.8 |
| Dicky ............ | 541 | 541 | 0 | .. | 100.0 |
| Excelsior ......... | 385 | 384 | 1 | .. | 99.7 |
| Gandy ........... | 468 | 455 | 9 | 4 | 97.2 |
| Golden Gate ...... | 180 | 168 | 4 | 8 | 93.4 |
| Longfellow ....... | 141 | 141 | 0 | .. | 100.0 |
| Marshall ......... | 255 | 220 | 35 | .. | 86.3 |
| Dunlap ........... | 667 | 667 | 0 | .. | 100.0 |
| Glen Mary........ | 30 | 16 | 14 | .. | 53.3 |
| *F. chiloensis*...... | 184 | 184 | 0 | .. | 100.0 |
| *F. elatior*......... | 303 | 302 | 1 | .. | 99.7 |
| *F. virginiana* .... | 572 | 276 | 296 | .. | 48.3 |
| Total .......... | 4,382 | 3,956 | 414 | 12 | 90.3 |
| Total excluding three species and Glen Mary (small numbers) | 3,293 | 3,178 | 103 | 12 | 96.5 |

A high degree of purity as to sex is revealed, conforming closely to the parent type of flower. Dicky, Longfellow, Dunlap and *F. chiloensis* came 100 percent perfect like their respective mother plants, while Excelsior was almost so, being 99.7 percent perfect in flower structures. However, Marshall returned only 86 percent, and Glen Mary only 53 percent perfect. Moreover, the native plants returned less than half perfect plants. Exclusive of Glen Mary, *F. chiloensis, F. elatior* and some native forms, the percentage of sexual perfectness is 96.5, a figure near enough to totality to justify classifying the first eight varieties listed in table V as stable bisexual forms.

The second generation of self-pollinated plants, using only perfects of the first generation, was grown with the following results:

TABLE VI.—SECOND GENERATION OF SELF-POLLINATED PERFECT VARIETIES

| | | Number of progeny | | | |
|---|---|---|---|---|---|
| Parent | Total | Perfect | Imperfect | Semi-perfect | Percentage perfect |
| Barrymore ....... | 328 | 328 | 0 | 0 | 100.0 |
| Dicky ............ | 334 | 334 | 0 | 0 | 100.0 |
| Excelsior ......... | 240 | 239 | 1 | 0 | 99.6 |
| Gandy ........... | 733 | 716 | 17 | 0 | 97.7 |
| Golden Gate ...... | 149 | 149 | 0 | 0 | 100.0 |
| Longfellow ....... | 40 | 40 | 0 | 0 | 100.0 |
| Marshall ......... | 195 | 195 | 0 | 0 | 100.0 |
| Dunlap ........... | 93 | 93 | 0 | 0 | 100.0 |
| *F. chiloensis* ..... | 190 | 190 | 0 | 0 | 100.0 |
| *F. elatior* ........ | 290 | 290 | 0 | 0 | 100.0 |
| *F. virginiana* ..... | 62 | 62 | 0 | 0 | 100.0 |
| Total .......... | 2,654 | 2,636 | 18 | 0 | 99.3 |

Only two varieties, Excelsior and Gandy, lacked or failed fully to carry the necessary factor for perfect flowered progeny. Excelsior lacked only 0.4 percent for perfect flowered progeny, Gandy disclosed 2.3 percent of sexual imperfection in the second generation. Evidently these two varieties were more difficult than the other nine to fix as constant bisexual forms.

The self-pollination trials were projected into the third generation in the case of Barrymore, Dicky, Excelsior, Gandy and *F. chiloensis* with results as follows:

TABLE VII.—THIRD GENERATION OF SELF-POLLINATED PERFECT VARIETIES

| Parent | Number of progeny Total | Perfect | Imperfect | Semi-perfect | Percentage perfect |
|---|---|---|---|---|---|
| Barrymore ....... | 124 | 117 | 7 | 0 | 94.4 |
| Dicky ............ | 25 | 25 | 0 | 0 | 100.0 |
| Excelsior ......... | 142 | 139 | 3 | 0 | 97.9 |
| Gandy ........... | 822 | 745 | 71 | 6 | 90.6 |
| Total .......... | 1,113 | 1,026 | 81 | 6 | 92.2 |
| *F. chiloensis* ..... | 750 | 750 | 0 | 0 | 100.0 |
| All varieties ...... | 1,863 | 1,776 | 81 | 6 | 95.3 |

In this last instance all four varieties, Barrymore, Dicky, Excelsior and Gandy, gave over 90 percent perfect flowered progeny, with Dicky yielding 100 percent. It appears that some varieties are difficult to establish as absolute bisexual constants, although most varieties can be fixed so as to yield a sufficiently high percentage for practical purposes.

### STABILITY OF WEAK POLLENIZERS

There are several varieties of strawberries, such as Excelsior and Glen Mary, which have been classed as weak pollenizers. In the early part of their blossoming period they produce but little pollen, seldom enough to set their own fruits. Later on pollen becomes more abundant. They are, therefore, considered poor pollenizers to interplant among pistillate varieties. Glen Mary is regarded by some strawberry growers as semi-perfect and, therefore, held by some to be a transitional form between the perfects and the imperfects. If this is so, it might be considered as somewhat unstable in its sexual morphology. It seemed desirable to pollinate both Excelsior and Glen Mary and observe the flower structure among the offspring. Consequently a large number of plants were self-fertilized and the sexual nature of their offspring observed and recorded.

The 21 Excelsior plants which were used as mothers gave rise to 324 new plants, all but four of which were perfect in their blossom structure. When Glen Mary was used, 23 out of 25 came true to the mother plant and were perfect in sexual development; one was imperfect while the other bore trusses with some unisexual and some bisexual flowers. The unisexual forms were so few in number that it was impossible to recognize any appreciable sexual hybridity. For all practical purposes, therefore, the mother plants were found to be sexually stable. As is usually the case with Glen Mary and Excelsior, an insufficiency of pollen was produced during the first few days of blossoming.

## INHERITANCE AND TRANSMISSION OF SEX IN CROSSES BETWEEN PERFECT AND IMPERFECT VARIETIES

The third phase of the general problem of sterility had to do with the inheritance and transmission of sex when crosses were made between perfect and imperfect varieties. The purpose in hybridizing unisexual and bisexual forms was to ascertain the possibility of inbreeding the missing sex. The imperfect varieties, Warfield, Cardinal, Haverland and Sample, were crossed with Barrymore, Dicky, Gandy, Golden Gate, Marshall and Dunlap. In some cases the progeny were recrossed with the staminate parent, while in other instances the perfect flowered plants from the first generation were self-pollinated as indicated in the subjoined tables.

### WARFIELD CROSSED WITH PERFECT VARIETIES

The sexual character of the progeny resulting from the crossing of Warfield with perfect forms like Barrymore, Dicky, Gandy and Golden Gate is shown as follows:

TABLE VIII.—CROSSES BETWEEN WARFIELD AND PERFECT VARIETIES

| Parents | | Generation | Number of progeny | | | Percentage perfect |
|---|---|---|---|---|---|---|
| Imperfect | Perfect | | Total | Perfect | Imperfect | |
| Warfield × | Barrymore | first | 196 | 94 | 102 | 48.0 |
| | | second | 181 | 164 | 17 | 90.6 |
| | | third | 1 | 1 | 0 | 100 |
| Warfield × | Dicky | first | 217 | 96 | 121 | 44.2 |
| | | second | 196 | 177 | 19 | 90.3 |
| Warfield × | Gandy | first | 349 | 190 | 159 | 54.4 |
| | | second | 1,906 | 1,891 | 15 | 99.2 |
| | | third | 298 | 287 | 11 | 96.3 |
| Warfield × | Golden Gate | first | 57 | 29 | 28 | 50.9 |
| | | second | 440 | 401 | 39 | 91.1 |

The distribution of unisexual and bisexual flowers in the crosses as presented in the above table shows the first trend of sex inheritance.

*Warfield crossed with Barrymore.*—Warfield is one of the best pistillate varieties on the market. It is generally recommended because of its size, general attractiveness and especially for its superior shipping qualities. It originated in 1885 as the supposed product of a cross between Crescent and Wilson, the former being pistillate, the latter staminate. Barrymore is a bisexual variety of unknown origin, although Sample is thought to have been one of its parents. As a result of this first cross 196 plants were secured, 94 of which were perfect and 102 imperfect. When the perfect forms of this generation were self-pollinated, there were raised 181 plants, 164 of which were perfect and 17 imperfect. The proportions of perfects and imperfects in the first generation were closely identical, but in the second test the selfing process seemed to show that some of the perfects in the first generation, although apparently perfects, in reality were in part imperfect, as shown in the segregation which occurred upon self-pollination, there being 17 imperfects that were dissociated out of 181 plants of mixed sexuality.

*Warfield crossed with Dicky.*—Dicky is a perfect flowered variety, although probably hybrid in its sexual makeup, for one of its parents (Sample) is pistillate. As a result of crossing Warfield with Dicky, 217 plants were secured which, upon flowering, exhibited 96 perfect and 121 imperfect plants, a ratio of approximately four to five. The high proportion of unisexual plants probably can be attributed to the occurrence of pistillate forms among the ancestors of both Warfield and Dicky, despite the fact that the apparent pure bisexuality of the latter variety was exhibited in the self-pollination trials. However, different plants were used in the two experiments.

*Warfield crossed with Gandy.*—Gandy is a bisexual variety, bearing both stamens and pistils of good vigor. It came into existence as the product of a cross between Jersey Queen, a pistillate, and Glendale, a bisexual. From the records, it appears that pistillate ancestry exists for both of these parent varieties. A progeny of 349 plants was secured, of which 190 were bisexual and 159 unisexual. There were no intermediate forms. Since Warfield bears no pollen it could not have been "purified" or "fixed" as to sex and, therefore, was probably more or less hybrid in sexual structure, unless it is assumed that its pistillate character is a Mendelian segregation. In the second generation of self-pollinated plants all but 15 of the 1,906 plants produced were perfect (99.2 percent). In the third generation, only 11 imperfects appeared among 298 plants (96.3 percent).

*Warfield crossed with Golden Gate.*—The Golden Gate variety is recorded as being staminate to semi-staminate. It originated in 1903 as a supposed seedling of Marshall, a bisexual variety of unknown parentage. Fifty-seven plants were secured, 29 of which were perfect and 28 imperfect. When the perfects were self-pollinated, a progeny of 440 was secured, 401 of which were perfect and 39 were imperfect (91.1 percent perfect).

When Warfield, an imperfect flowered plant, was mated with several perfect varieties, a nearly equal number of unisexual and bisexual plants were secured in the first generation. When perfects of the first generation were self-pollinated, a preponderance of perfects resulted, although there was some segregation, and a few more imperfects appeared, showing that the first separation on the basis of sex, while not absolutely complete, was reasonably so.

## HAVERLAND CROSSED WITH PERFECT VARIETIES

Haverland, another imperfect flowered plant, was mated with Barrymore, Dicky, Gandy, Golden Gate, Marshall and Dunlap—all perfect flowered forms, with results as shown in the subjoined table.

TABLE IX.—CROSSES BETWEEN HAVERLAND AND PERFECT VARIETIES

| Parents | | Generation | Number of progeny | | | | Percentage perfect |
|---|---|---|---|---|---|---|---|
| Imperfect | Perfect | | Total | Perfect | Imperfect | Semi-perfect | |
| Haverland × | Barrymore | first | 39 | 18 | 21 | 0 | 46.2 |
| | | second | 104 | 104 | 0 | 0 | 100 |
| Haverland × | Dicky | first | 188 | 96 | 92 | 0 | 51.1 |
| | | second | 197 | 185 | 12 | 0 | 93.9 |
| | | third | 69 | 69 | 0 | 0 | 100 |
| Haverland × | Gandy | first | 114 | 61 | 53 | 0 | 53.5 |
| | | second | 844 | 844 | 0 | 0 | 100 |
| | | third | 90 | 74 | 11 | 5 | 82.2 |
| Haverland × | Golden Gate | first | 122 | 57 | 65 | 0 | 46.7 |
| | | second | 43 | 43 | 0 | 0 | 100 |
| | | third | 111 | 111 | 0 | 0 | 100 |
| Haverland × | Marshall | first | 68 | 46 | 22 | 0 | 67.6 |
| | | second | 16 | 16 | 0 | 0 | 100 |
| | | third | 35 | 34 | 1 | 0 | 97.1 |
| Haverland × | Dunlap | first | 5 | 2 | 3 | 0 | 40 |

*Haverland crossed with Barrymore.*—Haverland is a pistillate variety which originated in 1882 as the product of a cross between Crescent, a pistillate, and Sharpless, a perfect variety, and was introduced to the trade in 1887. Its pistillate character was probably derived from its mother (Crescent). The variety Barrymore, as previously mentioned, is a perfect variety, whose origin is not definitely known. The progeny obtained as a result of the cross were about evenly divided between perfects and imperfects, there being 18 perfect, and 21 imperfect plants. When the perfect plants in this progeny were self-pollinated, there resulted 104 plants, which were all perfect.

*Haverland crossed with Dicky.*—The variety Dicky was derived from Sample, a pistillate, crossed with Marshall, a perfect. The latter variety probably transmitted all of its sexual structures to Dicky. With Haverland as a mother, crosses were made with pollen from Dicky. As a result, 188 seedlings were secured which, upon blossoming, gave 96 plants with perfect flowers and 92 with imperfect ones. In the first generation, the sexes appeared in nearly equal numbers. In the second generation—secured by selfing the perfects of the first generation—197 plants were secured, 185 of which were perfect, and 12 were imperfect (93.9 percent perfect). When the perfect forms derived from the self-pollinated perfects were again selfed, there were 96 plants all of which were perfect flowered.

*Haverland crossed with Gandy.*—Gandy is a perfect flowered variety which originated in Newport, N. J., in 1885 as the product of a cross between Jersey Queen, a pistillate, and Glendale, a staminate. With the first named variety as a mother plant, 22 plants were fertilized and 114 progeny raised from the cross, 61 of which were perfect flowered and 53 imperfect. Following self-pollination of some of the 61 plants which were perfect, 844 perfect flowered plants were secured, but when these were again self-pollinated, the 90 plants produced showed segregation, for there were 74 perfect, 11 imperfect and five with both flower types on the same truss. This late segregation seems like a reversion to Haverland structures.

Haverland when crossed with Golden Gate, Dunlap and Marshall afforded results similar to those secured with Gandy, Dicky and Barrymore.

Table X sets forth the number of perfect and imperfect progeny resulting when Cardinal, an imperfect variety, was crossed with three perfect varieties (Excelsior, Longfellow and Dunlap) and when Sample, another imperfect, was crossed with three perfects (Excelsior, Gandy and Longfellow).

TABLE X.—CROSSES OF CARDINAL AND SAMPLE WITH PERFECT VARIETIES

| Parents | | Generation | Number of progeny | | | Percentage perfect |
|---|---|---|---|---|---|---|
| Imperfect | Perfect | | Total | Perfect | Imperfect | |
| Cardinal × | Excelsior | first | 216 | 122 | 94 | 56.5 |
| | | second | 17 | 17 | 0 | 100 |
| Cardinal × | Longfellow | first | 286 | 148 | 138 | 51.7 |
| | | second | 45 | 45 | 4 | 100 |
| Cardinal × | Dunlap | first | 214 | 143 | 71 | 66.8 |
| | | second | 53 | 53 | 0 | 100 |
| Sample × | Excelsior | first | 333 | 205 | 128 | 61.6 |
| | | second | 27 | 27 | 0 | 100 |
| | | third | 13 | 13 | 0 | 100 |
| Sample × | Gandy | first | 163 | 88 | 75 | 54 |
| | | second | 97 | 97 | 0 | 100 |
| | | third | 23 | 23 | 0 | 100 |
| Sample × | Longfellow | first | 66 | 44 | 22 | 66.7 |
| | | second | 94 | 94 | 0 | 100 |

*Cardinal crossed with Excelsior.*—Cardinal (of Streator), a pistillate variety, is a supposed seedling of Warfield, also a pistillate variety. Excelsior (of Hubach) has been classed as a semi-perfect, possessing impotent pollen at the beginning of its blossoming period but producing potent pollen later. Two hundred and sixteen progeny were secured, 122 of which were perfect and 94 imperfect. In the second generation, resulting from self-pollination of the perfects, 17 plants were raised, all of which were perfect.

*Cardinal crossed with Longfellow.*—This cross gave 286 plants, 148 of which were perfect and 138 imperfect. By selfing the perfects 48 plants were secured, all of which were perfect flowered.

*Cardinal crossed with Dunlap.*—The Dunlap variety, of which is of uncertain sexual ancestry, when crossed with Cardinal, gave 214 plants, 143 of which were perfect and 71 imperfect. By selfing the perfects there came into being 53 new perfect-flowered plants.

Sample when crossed with Excelsior, Gandy and Longfellow afforded results similar in all respects to those secured with Cardinal.

## BACK-CROSSES WITH HAVERLAND AND WARFIELD

Back-crosses, known as sesqui-hybrids, were made by pollinating some of the plants derived from the first cross with the paternal parent of the first cross. The data appear below:

TABLE XI.—BACK-CROSSES WITH THE PERFECT PARENT

FIRST GENERATION

| Parents | | Number of progeny Total | Perfect | Imperfect | Percentage perfect |
|---|---|---|---|---|---|
| Haverland × Dicky | × Dicky | 49 | 46 | 3 | 95.8 |
| Haverland × Golden Gate | × Golden Gate | 7 | 3 | 4 | 42.9 |
| Warfield × Barrymore | × Barrymore | 510 | 247 | 263 | 48.4 |
| Warfield × Dicky | × Dicky | 208 | 101 | 107 | 48.6 |
| Warfield × Golden Gate | × Golden Gate | 68 | 64 | 4 | 94.1 |
| | Total | 842 | 461 | 381 | 54.8 |

When Dicky, a perfect, was used to back-pollinate the first generation derived from Haverland crossed with Dicky, only the segregated perfect were used and as a result 46 out of 49 plants were perfect, while only three were unisexual. The back-cross of the progeny of Warfield crossed with Golden Gate, which was re-pollinated with Golden Gate, gave 64 perfects out of a possible 68, there being only four imperfects that were segregated.

In the other three cases of back-crossing the segregated imperfects of the first generation were used, and these gave results similar to those secured in the original crosses of perfects and imperfects, namely, nearly equal proportions of unisexuals and bisexuals. Upon self-pollination of the perfects a replication of the results of the first cross occurred, for all the progeny came perfect.

Table XI set forth the results of back-crossing the first generation perfects with their male parents. Table XII exhibits the progeny which resulted from the self-pollination of the progeny of the back-crosses.

### TABLE XII.—BACK-CROSSES WITH THE PERFECT PARENT

SECOND GENERATION

| Parents | | Number of progeny | | | Percentage perfect |
|---|---|---|---|---|---|
| | | Total | Perfect | Imperfect | |
| Haverland<br>×<br>Dicky | × Dicky | 86 | 86 | 0 | 100 |
| Haverland<br>×<br>Golden Gate | × Golden Gate | 31 | 31 | 0 | 100 |
| Warfield<br>×<br>Dicky | × Dicky | 101 | 101 | 0 | 100 |
| Warfield<br>×<br>Golden Gate | × Golden Gate | 76 | 76 | 0 | 100 |
| | Total | 294 | 294 | 0 | 100 |

## CROSSES OF PERFECT AND IMPERFECT VARIETIES

Table XIII assembles all of the data on the first generation crosses

### TABLE XIII.—COMBINED TABLE OF CROSSES—FIRST GENERATION

| Parents | | | Number of progeny | | | Percentage perfect |
|---|---|---|---|---|---|---|
| Imperfect | | Perfect | Total | Perfect | Imperfect | |
| Haverland | × | Barrymore | 39 | 18 | 21 | 46.2 |
| Haverland | × | Dicky | 188 | 96 | 92 | 51.1 |
| Haverland | × | Gandy | 114 | 61 | 53 | 53.5 |
| Haverland | × | Golden Gate | 122 | 57 | 65 | 46.7 |
| Haverland | × | Marshall | 68 | 46 | 22 | 67.6 |
| Haverland | × | Dunlap | 5 | 2 | 3 | 40 |
| | | Total | 536 | 280 | 256 | 52.2 |
| Warfield | × | Barrymore | 196 | 94 | 102 | 48 |
| Warfield | × | Dicky | 217 | 96 | 121 | 44.2 |
| Warfield | × | Gandy | 349 | 190 | 159 | 54.2 |
| Warfield | × | Golden Gate | 57 | 29 | 28 | 50.9 |
| | | Total | 819 | 409 | 410 | 49.9 |
| Cardinal | × | Excelsior | 216 | 122 | 94 | 56.5 |
| Cardinal | × | Longfellow | 286 | 148 | 138 | 51.7 |
| Cardinal | × | Dunlap | 214 | 143 | 71 | 66.8 |
| | | Total | 716 | 413 | 303 | 57.7 |
| Sample | × | Excelsior | 333 | 205 | 128 | 61.6 |
| Sample | × | Gandy | 163 | 88 | 75 | 54 |
| Sample | × | Longfellow | 66 | 44 | 22 | 66.7 |
| | | Total | 562 | 337 | 225 | 60 |
| Crosses with Haverland | | | 536 | 280 | 256 | 52.2 |
| Crosses with Warfield | | | 819 | 409 | 410 | 49.9 |
| Crosses with Cardinal | | | 716 | 413 | 303 | 57.7 |
| Crosses with Sample | | | 562 | 337 | 225 | 60 |
| | | Total | 2,633 | 1,439 | 1,194 | 54.7 |

and enables a ready comparison of the inheritance of bisexual and unisexual flower types for the several varieties used. In mating Haverland with several bisexual forms a total of 536 plants were obtained, 280 of which were bisexual and 256 were unisexual; in mating Warfield with several bisexuals as listed, 819 plants were secured of which 409 were bisexual and 410 unisexuals; in mating Cardinal with three perfect varieties, 716 plants were secured of which 413 were bisexual and 303 unisexual; and in mating Sample with three perfects, 566 plants were secured, 337 of which were bisexual and 225 unisexual. The sum total for all crosses was 1,439 bisexuals and 1,194 unisexuals, or a proportion of about seven to six.

Tables XIV and XV show the combined results for the second and third generation of crosses.

TABLE XIV.—COMBINED TABLE OF SECOND GENERATION PLANTS

RESULTS OF SELF-POLLINATION OF PERFECTS OF THE FIRST GENERATION

| Parents | | Number of progeny | | | Percentage |
|---|---|---|---|---|---|
| Imperfect | Perfect | Total | Perfect | Imperfect | perfect |
| Haverland | × Barrymore | 104 | 104 | 0 | 100 |
| Haverland | × Dicky | 197 | 185 | 12 | 93.9 |
| Haverland | × Gandy | 844 | 844 | 0 | 100 |
| Haverland | × Golden Gate | 43 | 43 | 0 | 100 |
| Haverland | × Marshall | 16 | 16 | 0 | 100 |
| | Total | 1,204 | 1,192 | 12 | 99 |
| Warfield | × Barrymore | 181 | 164 | 17 | 90.6 |
| Warfield | × Dicky | 196 | 177 | 19 | 90.3 |
| Warfield | × Gandy | 1,906 | 1,891 | 15 | 99.2 |
| Warfield | × Golden Gate | 440 | 401 | 39 | 91.1 |
| | Total | 2,723 | 2,633 | 90 | 96.7 |
| Cardinal | × Excelsior | 17 | 17 | 0 | 100 |
| Cardinal | × Longfellow | 45 | 45 | 0 | 100 |
| Cardinal | × Dunlap | 53 | 53 | 0 | 100 |
| | Total | 115 | 115 | 0 | 100 |
| Sample | × Excelsior | 27 | 27 | 0 | 100 |
| Sample | × Gandy | 97 | 97 | 0 | 100 |
| Sample | × Longfellow | 94 | 94 | 0 | 100 |
| | Total | 218 | 218 | 0 | 100 |
| Crosses with Haverland | | 1,204 | 1,192 | 12 | 99 |
| Crosses with Warfield | | 2,723 | 2,633 | 90 | 96.7 |
| Crosses with Cardinal | | 115 | 115 | 0 | 100 |
| Crosses with Sample | | 218 | 218 | 0 | 100 |
| | Total | 4,260 | 4,158 | 102 | 97.6 |

TABLE XV.—COMBINED TABLE OF THIRD GENERATION PLANTS

RESULTS OF SELF-POLLINATION OF PERFECTS OF THE SECOND GENERATION

| Parents | | | Number of progeny | | | |
|---|---|---|---|---|---|---|
| Imperfect | Perfect | Total | Perfect | Imperfect | Semi-perfect | Percentage perfect |
| Haverland × | Dicky | 69 | 69 | 0 | .. | 100 |
| Haverland × | Gandy | 90 | 74 | 11 | 5 | 82.2 |
| Haverland × | Golden Gate | 111 | 111 | 0 | .. | 100 |
| Haverland × | Marshall | 35 | 34 | 1 | .. | 97.1 |
| | Total | 305 | 288 | 12 | 5 | 94.4 |
| Warfield × | Barrymore | 1 | 1 | 0 | .. | 100 |
| Warfield × | Gandy | 298 | 287 | 11 | .. | 96.3 |
| | Total | 299 | 288 | 11 | .. | 96.3 |
| Sample × | Excelsior | 13 | 13 | 0 | .. | 100 |
| Sample × | Gandy | 23 | 23 | 0 | .. | 100 |
| | Total | 36 | 36 | 0 | .. | 100 |
| Crosses with Haverland | | 305 | 288 | 12 | 5 | 94.4 |
| Crosses with Warfield | | 299 | 288 | 11 | .. | 96.3 |
| Crosses with Sample | | 36 | 36 | 0 | .. | 100 |
| | Total | 640 | 612 | 23 | 5 | 95.6 |

## SUMMARY OF ALL POLLINATIONS

All of the sex inheritance data discussed on the previous pages have been self-related in table XVI. It will be noticed that the first

TABLE XVI.—SUMMARY OF ALL STRAWBERRY SEX DATA

| | | | Number of progeny | | | |
|---|---|---|---|---|---|---|
| Treatment | Generation | Total | Perfect | Imperfect | Semi-perfect | Percentage perfect |
| Open pollinated— | | | | | | |
| Perfects | first | 940 | 927 | 13 | 0 | 98.6 |
| | second | 188 | 188 | 0 | 0 | 100 |
| Imperfects | first | 557 | 305 | 250 | 2 | 54.7 |
| Semi-perfect | first | 290 | 262 | 23 | 5 | 90.3 |
| | second | 27 | 27 | 0 | 0 | 100 |
| Hautbois | first | 151 | 151 | 0 | 0 | 100 |
| | second | 39 | 39 | 0 | 0 | 100 |
| Chilean | first | 37 | 37 | 0 | 0 | 100 |
| Self-pollinated— | | | | | | |
| Perfects | first | 4,382 | 3,956 | 414 | 12 | 90.3 |
| | second | 2,654 | 2,636 | 18 | 0 | 99.3 |
| | third | 1,863 | 1,776 | 81 | 6 | 95.3 |
| Cross-pollinated— | | | | | | |
| | first | 2,633 | 1,439 | 1,194 | 0 | 54.7 |
| | second | 4,260 | 4,158 | 102 | 0 | 97.6 |
| | third | 640 | 612 | 23 | 5 | 95.6 |
| Back-crossed— | | | | | | |
| | first | 842 | 461 | 381 | 0 | 54.8 |
| | second | 294 | 294 | 0 | 0 | 100 |

generation plants resulting from both the open and the self-pollination of perfect varieties for the most part were perfect; that in the second generation a still larger proportion of perfect plants developed; and that the third generation of self-pollinated plants showed a somewhat larger percentage of imperfects than were found in the second generation. The open-pollination of imperfect varieties gave results similar to those obtained from the crossing of perfect with imperfect varieties, in that there was a nearly equal number of unisexuals and bisexuals in the first generation. The back-crosses of the first generation progeny resulting from the cross-pollinations with the male parent also gave about the same number of perfects as of imperfects.

It is quite clear that it is possible to breed perfects and imperfects with considerable degree of definiteness; that unisexual forms were perpetuated in considerable numbers even though bred with perfect ones; and that some semi-perfect plants were segregated.

## INHERITANCE OF CHARACTERS IN NORTH AMERICAN VARIETIES OF THE STRAWBERRY

Preliminary to the inauguration of the experimental study of inheritance irrespective of sex, the data contained in Fletcher's (9) "North American Varieties of the Strawberry" were carefully surveyed. It has been possible in this compiled description of many varieties in part to trace the derivation of certain characters and likewise to follow the transmission of these characters to their descendants. The characteristics chosen were quality, shape, season, runner formation, color of flesh, flavor, surface color and size of berries. In these assembled data the Bubach, Crescent, Sample, Warfield, and Wilson were used, together with certain varieties that were mated with them.

*Quality of Fruit.*—Interesting results were found with regard to the transmission of quality characteristics from the parents to the offspring. In three instances where the factor for poor quality was crossed with that for good there resulted a good quality variety. When fair quality varieties were crossed with other fair ones there were produced one poor, five fair and four good varieties. Fair quality crossed with good resulted in 49 offspring which were divided on a percentage basis into classes as follows: poor, 1; fair, 18; good, 28; and very good, 2. When a fair and a very good quality variety were bred together a variety of a fair quality was created. When good was crossed with good there were 15 progeny, distributed into: poor, 1; fair, 2; good, 8; very good, 1. When good and very good varieties were crossed, there were produced one fair variety, three good and one very good.

It appears that some good quality offspring were derived from poor quality parents and that even when the parents were rated only as fair or good a few very good quality descendants were secured. Moreover, some good and very good varieties gave rise to some of only fair quality. This would seem to indicate that some segregation occurs on the basis of quality. Some blending was also noted when varieties with different quality grades were crossed. Table XVII gives these results in tabular form.

TABLE XVII.—INHERITANCE OF QUALITY

| Factors crossed | Number of progeny | Distribution of progeny | | | |
|---|---|---|---|---|---|
| | | Poor | Fair | Good | Very good |
| Poor × Good | 3 | .. | .. | 3 | .. |
| Fair × Fair | 10 | 1 | 5 | 4 | .. |
| Fair × Good | 49 | 1 | 18 | 28 | 2 |
| Fair × Very good | 1 | .. | 1 | .. | .. |
| Good × Good | 15 | 1 | 2 | 8 | 4 |
| Good × Very good | 5 | .. | 1 | 3 | 1 |

*Shape of Fruit.*—In a study of the inheritance of shape characteristics, 18 sets of crosses giving rise to 72 varieties were used from the list given by Fletcher. Table XVIII shows the distribution.

TABLE XVIII.—INHERITANCE OF SHAPE OF FRUIT IN STRAWBERRIES

R. = round; C. = conic; L. = long; W. = wedge; Cox. = cox-combed; O. = ovate; Ob. = obovate; Irreg. = irregular; R. C. = round-conic, etc.

| Factors crossed | Number of progeny | Distribution of progeny |
|---|---|---|
| R. C. × R. C. | 24 | 13 R. C.—4 C.—2 L. C.—2 R.—W. C. R. to W.—C. to W. |
| Irreg. C. × R. C. | 9 | 4 R. C.—2 R. C. to W.—R. C. to C.— R.—C. to W. |
| R. C. × W. C. | 6 | 3 R. C. to W. C.—R. C. to W.—C.— R. C. |
| R. C. × C. | 5 | 3 R. C.—C.—R. |
| Irreg. C. × C. to W. C. | 5 | Cox.—Irreg. O.—R. C. to W.—2 R. C. 2 R. C. |
| R. C. × R. | 3 | C.—R. to W. C.—L. C. |
| R. C. × Irreg. | 3 | R. C.—R. C. to W. C.—Irreg. C. |
| C. × C. | 3 | 2 R. C.—L. C. |
| Irreg. C. × C. | 2 | C. to W.—O. to W. |
| Irreg. C. × L. C. | 2 | R. C.—L. C. |
| R. C. × W. C. | 2 | R.—Irreg. |
| R. C. × Ob. C. to Cox. | 2 | Ob. C.—R. C. |
| R. C. × R. or Cox. | 1 | R. C. to O. C. |
| C. × R. C. to W. | 1 | L. C. |
| R. C. × Irreg. R. | 1 | R. Ob. |
| R. C. × R. C. to Cox. | 1 | R. C. |
| R. C. × R. C. to W. | 1 | W. C. |
| C. × L. O. | 1 | L. C. |

Segregation of the several shape factors occurred in cases where the progeny were numerous enough to permit of a distribution. In the first case, for instance, in which there were 24 varieties in the progeny, 13, or more than half, had berries that were round-conic in shape like both parents; yet four were conic and two were round. In the fourth instance (round-conic crossed with conic) the progeny contained three round-conic, one conic and one round berry. In the progeny of the third cross listed there was very noticeable segregation, for when round-conic and wedge-conic were crossed, three out of the six resultant varieties were round-conic to wedge-conic, one was round-conic to wedge, one was round-conic and the other was conic.

*Season of Ripening.*—Seven sets of crosses were found listed by Fletcher, from which enough offspring were grown to make it worth while to consider them in relation to the season of ripening. Table XIX presents the comparisons.

TABLE XIX.—INHERITANCE OF SEASON OF RIPENING

E. = early; M. E. = medium early; M. = mid-season; M. L. = medium late; V. L. = very late.

| | | Distribution of progeny | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Factors crossed | Number of progeny | Very early | Early | Medium early | Mid-season | Medium late | Late | Very late |
| E. × M. E. | 4 | 1 | 2 | 1 | .. | .. | .. | .. |
| E. × M. | 7 | .. | .. | 5 | 2 | .. | .. | .. |
| M. E. × M. E. | 9 | 1 | 4 | 1 | 1 | 2 | .. | .. |
| M. E. × M. | 8 | .. | .. | 3 | 3 | .. | 2 | .. |
| M. E. × M. L. | 12 | .. | .. | 2 | 6 | 3 | .. | 1 |
| M. E. × V. L. | 3 | .. | 1 | .. | 1 | .. | 1 | .. |
| M. × M. L. | 18 | .. | 1 | 2 | 11 | 2 | 2 | .. |

It will be noticed that while the ripening season of the offspring seems as a rule somewhat intermediate between that of its two parents, yet on the whole there is a marked tendency of all of the crosses toward the production of mid-season forms in the progeny.

*Runner Formation.*—Table XX sets forth data concerning the ability of the strawberry plant to form runners, as well as the transmission of this characteristic to new generations. The tendency in the

### TABLE XX.—INHERITANCE OF NUMBERS OF RUNNERS

F. = few; M. = moderate; N. = numerous; V. N. = very numerous

| Factors crossed | Number of progeny | Distribution of progeny<br>Few | Moderate | Numerous | Very numerous |
|---|---|---|---|---|---|
| F. × F. | 5 | 2 | 2 | 1 | .. |
| F. × M. | 17 | 4 | 8 | 5 | .. |
| F. × N. | 3 | .. | 1 | 2 | .. |
| M. × M. | 7 | .. | 4 | 3 | .. |
| M. × N. | 10 | 1 | 6 | 3 | .. |
| M. × V. N. | 18 | 1 | 3 | 12 | 2 |
| N. × V. N. | 9 | 1 | 4 | 4 | .. |

main is for the new varieties to fall into groups which are either like their parents or are closely related to them, rather than to scatter or to fall into remote groups.

*Color of Flesh.*—Table XXI exhibits data with regard to color of flesh in the progeny of five sets of crosses classified into four color groups.

### TABLE XXI.—INHERITANCE OF COLOR OF FLESH

W. = whitish; L. = light red; M. = medium red; D. = dark red.

| Factors crossed | Number of progeny | Distribution of progeny<br>Whitish | Light red | Medium red | Dark red |
|---|---|---|---|---|---|
| L. × L. | 14 | 1 | 7 | 3 | 3 |
| L. × M. | 11 | .. | 5 | 5 | 1 |
| L. × D. | 14 | .. | 4 | 8 | 2 |
| M. × M. | 13 | 1 | 1 | 6 | 5 |
| M. × D. | 12 | 1 | 1 | 6 | 4 |

For the most part the progeny resembled their parents in color. It is interesting to note, however, that six dark-fleshed varieties came from light-fleshed parents, that 16 other dark-fleshed varieties came from crosses in which one parent was light-fleshed, and that four whitish or light-fleshed progeny came from medium or dark red parents.

*Flavor of Fruit.*—Table XXII deals with the flavor of berries. As between parents and offspring, it was found in general that there

### TABLE XXII.—INHERITANCE OF FLAVOR

S. = sweet; M. S. A. = mild sub-acid; S. A. = sub-acid; B. S. A. = brisk sub-acid; A. = acid; V. A. = very acid

| Factors crossed | Number of progeny | Distribution of progeny<br>S. | M. S. A. | S. A. | B. S. A. | A. | V. A. |
|---|---|---|---|---|---|---|---|
| S. × A. | 5 | 2 | 1 | .. | .. | 2 | .. |
| M. S. A. × S. A. | 11 | 1 | 4 | 1 | 2 | 3 | .. |
| M. S. A. × A. | 9 | 1 | .. | 6 | .. | 2 | .. |
| S. A. × S. A. | 8 | 1 | 3 | 3 | 1 | .. | .. |
| S. A. × B. S. A. | 2 | 1 | .. | 1 | .. | .. | .. |
| S. A. × A. | 16 | 1 | 3 | 2 | 1 | 8 | 1 |
| A. × A. | 12 | .. | 1 | 1 | .. | 9 | 1 |

was segregation and scattering of flavors into many classes. In the first instance in which two contrasting flavors, sweet and acid, were bred together about an equal number of the offspring resembled each parent in flavor. When acid varieties were mated with each other and when acid was bred with sub-acid, there was a preponderance of acid varieties in the offspring.

*Surface Color of Fruit.*—Table XXIII is concerned with the inheritance of surface color of the fruit. There was a much scattered segregation, indicating hybrid factors for color even where contrasting colors were not employed in the crosses.

TABLE XXIII.—INHERITANCE OF COLOR OF FRUIT

C. = crimson; S. = scarlet; L. = light; B. = bright; D. = dark

| | | Distribution of progeny | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Factors crossed | Number of progeny | L. C. | B. C. | C. | D. C. | L. S. | B. S. | S. | D. S |
| L. C. × D. C. | 8 | 1 | 1 | .. | 3 | 1 | 1 | 1 | .. |
| L. C. × B. S. | 11 | 3 | 2 | 2 | 1 | .. | 1 | 2 | .. |
| D. C. × L. S. | 5 | .. | .. | 1 | 1 | 1 | .. | 2 | .. |
| D. C. × D. C. | 4 | 1 | .. | .. | 2 | .. | .. | 1 | .. |
| D. C. × B. S. | 15 | 4 | 1 | 2 | 5 | .. | 1 | 2 | .. |
| B. S. × B. S. | 12 | 1 | 4 | 1 | 2 | .. | .. | 2 | 2 |

*Size of Fruit.*—The data dealing with the inheritance of size are assembled in table XXIV. In this study it appears that there is some segregation of factors for size. In the first case in the table where small to medium were crossed with small to medium, there was one instance like either parent, four medium, and four medium to large. In most cases, however, the distribution is within rather than beyond the range of sizes possessed by the parents, still disclosing strong tendency to segregation.

TABLE XXIV.—INHERITANCE OF SIZE OF FRUIT

S. M. = small to medium; M. = medium; M. L. = medium to large;
L. = large; L. V. L. = large to very large

| | | Distribution of progeny | | | | |
|---|---|---|---|---|---|---|
| Factors crossed | Number of progeny | Small to medium | Medium | Medium to large | Large | Large to very large |
| S. M. × S. M. | 9 | 1 | 4 | 4 | .. | .. |
| S. M. × L. | 13 | 6 | 6 | 1 | .. | .. |
| M. × M. | 6 | 1 | 4 | .. | 1 | .. |
| M. × L. | 9 | .. | 3 | .. | 6 | .. |
| M. × L. V. L. | 14 | .. | 5 | 4 | 5 | .. |
| M. L. × L. V. L. | 8 | .. | 3 | 2 | 3 | .. |
| L. × L. V. L. | 8 | .. | .. | 4 | 3 | 1 |

*Summary.*—Quality, shape, color of flesh, surface color, and flavor of the berry. The progeny resulting from the various crosses were distributed into several classes, even when varieties similar in respect to the character in question were mated.

Size of fruit, number of runners. There was a marked correlation between the parent and the offspring, and not quite as wide a scattering into different classes as occurred in the case of the previously mentioned characters.

Season. There was a marked tendency toward the production of mid-season forms, regardless of the seasonal characteristics of the parents.

While the data presented in the preceding study of inheritance are not sufficiently extensive to make it possible to predict what results would occur from a given mating, yet they are suggestive of what might be expected. The hybrid nature of the American varieties of strawberries is shown quite clearly by the "splitting up" of factors which occurs when definite breeding work is undertaken.

## RESULTS OF BREEDING EXPERIMENTS

### Comparison of Progeny With Parents

After thus discussing the results of the breeding experiments with respect to the inheritance of flower structures and the segregation of the same in the progeny, it now becomes necessary to compare in some detail the attributes and structural characteristics of the offspring, to note what effect the crossing has produced. This has been done for the varieties on record and must now be done for the sorts secured by breeding. The question arises in the new forms produced whether a new combination of characters occurs or the new sorts are simply slight modifications of the old varieties. In other words, can an imperfect-flowered variety be sexually reconstituted and still retain, or be made to possess, its primary varietal characteristics? If not in its entirety, to what extent can it be done?

The approach to this problem was made by comparing and analyzing several sets of crosses in which the same pistillate variety was crossed with several staminate varieties; for instance, Warfield was crossed with Barrymore, Gandy, Dicky and Golden Gate; Haverland was crossed with Dicky, Gandy, Golden Gate and Marshall; and Sample was crossed with Excelsior, Gandy and Longfellow. In some cases the contrasts in varietal characters of the parents used were quite marked; in others they were but slight. Original descriptions were made of nearly all varieties used for comparison with the progeny.

### WARFIELD CROSSED WITH BARRYMORE, GANDY, DICKY AND GOLDEN GATE

*Warfield crossed with Barrymore.*—Warfield may be characterized as a standard imperfect-flowered variety of early season. The berries are conic in shape, medium in size; calyx large, detached; surface of berry glossy, dark crimson; flesh dark red; seeds brown, prominent and protruding; texture firm, fine grained; core solid; flavor acid; quality fair. Barrymore is a staminate mid-season variety. The berries are round-conic and of medium size; calyx medium; surface color, light crimson; seeds depressed; flesh, light red; texture firm; core solid; flavor, mild sub-acid; quality, good.

The fruits secured from the plants arising from this cross were of medium size, conic, and dark crimson, with protruding seeds, firm flesh, and solid core like Warfield; but were like Barrymore in ripening in mid-season and in being sub-acid. Many of the plants, furthermore, possessed staminate blossoms. The plants were vigorous and formed numerous runners of fair length. The foliage was abundant, the leaves being of medium size and growing in a compact manner. The leaf stalks were of good length, being about four inches long, while the fruit stalks were unbranched, erect, and measured, on the average, 3½ inches in length, being of sufficient length to hold the berries up from the ground. The new plants were good ones.

The primary object of the cross was to study the segregation or combination of the sexes, while the secondary purpose was to analyze the new forms and to determine their merits. The results of the primary objects are set forth elsewhere in tabular form. The merits of the new forms are determined by comparing them with the parent varieties. Were the plants secured from this cross superior to Warfield? And were the essential Warfield characteristics lost in the mixture? The distinguishing attributes of Warfield are its pistillate flowers, its early season of ripening, its medium sized conic berry which is firm, solid at the center, and acid in flavor and its prominent protruding seeds. In the cross with Barrymore, the conic shape of the berry, the dark crimson color of the fruit, the protruding seeds and the firmness of flesh were all retained. Moreover, in the first generation with a total of 196 plants, 48 percent were perfect, while in the second generation in which there were 181 plants, 91 percent had perfect blossoms.

The new plants differed from Warfield in two unimportant characteristics. There was brought about a substitution of a hollow core for a solid one, and a somewhat deferred ripening season which coincides closely with that of the Barrymore. Nearly all of the essential features of Warfield were retained in the new forms. To a large extent the nature of the result is due to the general similarity of the parent varieties. The cross was not a violent one. The contrast between Warfield and Barrymore was not great, blossom structures and season of ripening constituting the chief differences. A later season of ripening is more than offset by the accompanying compensation of perfect flowers. Aside from the nature of the flowers and slight differences in the fruit the new forms were scarcely distinguishable from either parent plant. In the main, then, the Warfield strawberry was sexually reconstituted. By choosing for propagation the 91 percent of the progeny of the cross that had perfect flowers, one has for all practical purposes a staminate-flowered Warfield.

*Warfield crossed with Gandy.*—The distinguishing characteristics of Gandy are its large uniform roundish to conic berries of rich dark scarlet color, with numerous slightly protruding seeds; a hollow core and brisk sub-acid flavor; season of ripening very late. The berries on plants from this cross were like Warfield in size, in firmness of flesh, and in their dark crimson surface color, but they were like Gandy in being round-conic in shape, in producing small seeds and in possessing a sub-acid flavor. In common with both parents, the progeny bore protruding seeds and had firm-fleshed fruits. Some of the flowers produced were staminate and some were pistillate. In the first generation there were 349 plants, of which 190 were staminate and 159 pistillate. The second generation of this cross gave 1,906 plants, 1,891 being staminate and 15 pistillate. Core structures were of two kinds, some berries being solid like Warfield, some hollow like Gandy. The season of ripening was intermediate, neither early like Warfield nor late like Gandy, but mid-season.

*Warfield crossed with Dicky.*—The latter variety may be characterized as follows: Blossoms staminate; berry large, irregular, round-conic to wedge shape, often necked; surface color, bright crimson; flesh medium red, firm; flavor brisk sub-acid; quality fair; runner capacity, moderate; midseason. The plants arising from this cross produced berries that were like Warfield in color, being dark rather than light crimson, in bearing brown seeds and in ripening early. The berries were sweeter than those of Warfield, being judged as sub-

STRAWBERRY BREEDING

Above, seedling strawberry plants as grown in flat boxes in the greenhouse before being transplanted. One bench of bagged blossoms as done for self-pollination trials.

Below, pollination work in the garden.

acid, and therefore in flavor like Dicky. In flower structure many plants were of the Dicky type. In the first generation, of 217 plants under observation, 96 were perfect and 121 imperfect; and in the second generation, of 196 plants, 177 were perfect and 19 imperfect. Most of the berries possessed solid centers, although an occasional hollow core was found.

The Warfield characters that were lost, namely, protruding seeds and acid flavor, were not important, while those acquired were a better flavor and staminate flowers among some of the new forms. The firm flesh of both parents was retained as was the round-conic shape of the berry and the capacity to form runners freely. The plants of this cross were of strong constitution, low in stature, compact in growth and healthy. The large abundant leaves were borne or leaf stalks two inches in length. The fruit stalks were three inches long and were stout and branched like those of the Warfield.

It is clear that what was secured in this cross was either a remade Warfield or a Dicky with many Warfield attributes bred into it. It was a simple thing to perpetuate asexually the plants resulting from this cross and thus retain indefinitely any desired combination of Warfield or Dicky characteristics.

*Warfield crossed with Golden Gate.*—The characteristics of Golden Gate are its staminate blossoms; large sized fruit; large sunken seeds; dark crimson surface color; medium red, firm flesh; mild sub-acid flavor; good quality; and midseason of ripening. The fruits of the first generation of this cross were described as being ovate to conic, of medium size, dark red on the outside, with protruding reddish brown seeds of large size, with a sub-acid flavor and with a solid core. The season was early.

The second generation was different from the first with respect to seed placement in that the seeds were sunken in the flesh rather than protruding from it, and that the berries were attached to large reflexed calyces and were ridged, with an occasional one wedge-shaped at the apex, thus resembling Golden Gate. Some of the berries were necked as in Golden Gate. They were firm with solid centers and ripened in midseason, i. e., later than Warfield. In flower structure it was found in the first generation that of 57 plants 29 were bisexuals and 28 unisexuals, whereas in the second generation which resulted from the self-fertilization of perfects, 401 of the 440 plants were bisexuals. The chief Warfield characters were found in both generations. To be sure, the season was later, the flavor less acid and the flowers for the most part perfect; yet the berry was largely the Warfield improved and reinforced by the addition of certain desirable attributes.

In brief, the general effect of crossing Warfield with Barrymore, Gandy, Dicky and Golden Gate has been that of delaying the season of ripening by several days; of slightly modifying some of the more unessential structures or quality characteristics; and, what is of paramount importance, of introducing the pollen producing function by the inbreeding of staminate blossoms, thus sexually perfecting the plant and originating a new Warfield.

### HAVERLAND CROSSED WITH GOLDEN GATE, GANDY, MARSHALL AND DICKY

*Haverland crossed with Golden Gate.*—The distinguishing characteristics of the Haverland variety are the long conic berries; numerous large protruding seeds; firm flesh with a solid pink core; a mildly sub-acid flavor; pistillate flowers; with fruit ripening in midseason. Golden Gate differs from Haverland in having roundish to conic berries, which are dark crimson in color, with sunken seeds and perfect flowers. The attributes common to both varieties are the large seeds, firm flesh and midseason of ripening.

In the first generation of the cross the berries were oblong, conic, firm in flesh, light crimson in color, with large protruding seeds and had a midseason ripening period. The flowers were about half bisexual and half unisexual, for of 122 plants, 57 possessed both stamens and pistils while 65 had only pistils. In the second generation, the seeds were still prominent; the berries ripened in midseason, were round-conic, slightly necked, hollow at the cores, firm in flesh and sub-acid in flavor. The flowers were perfect in structure.

The new forms, with the exception of the ones in the second generation, were unlike Haverland in shape, as in general they were round-conic, rather than oblong-conic. They were about the same as Haverland in color, in flavor, in season of ripening, in seed characters and in firmness of flesh. The cores were often hollow rather than always solid. About half of those in the first generation were perfect while in the second generation all of the flowers were like those of the Golden Gate. Aside from the flowers and a few minor differences, these plants were new Haverlands, better in some respects than the old ones. The cross was a narrow one, few important differences occurring in the parent varieties and, therefore, striking differences were not expected. The similarity of the parents probably accounts for the fact that the offspring did not differ materially from either parent. The plants were strong, hardy but somewhat subject to leaf spot. They put forth runners very freely and produced an abundance of leaves, which formed a low compact mass of foliage. Moreover, the leaves were tough and had long stalks which were somewhat in excess of five inches. The fruit stalks were single, drooping and about four inches long.

*Haverland crossed with Gandy.*—The product of this cross gave berries that were like Haverland in ripening in midseason, in having pale red centers and in possessing prominent, protruding light brown seeds. They were like Gandy in being conic and wedge shaped and in having hollow centers. In common with both parents the fruit was of good quality, firm in texture and sub-acid in flavor. In the second generation some of the cores were hard and solid while others were hollow. Some of the calyces were recurved. The flowers in the first generation were of two types. Of 114 plants in the first generation, 61 were bisexuals, while in the second generation all of the 844 plants were bisexual. In this cross the Haverland seems to have taken on certain important Gandy attributes, especially flavor and flower structures. The plants were fairly productive and free from disease. The foliage was plentiful and the leaves of medium size with short leaf stalks. The fruit stalks were three inches long, branched and drooping.

*Haverland crossed with Marshall.*—The Marshall may be characterized as follows: Berry large, round-conic, often furrowed, dark crimson; calyx of medium size, slightly discolored; seeds large, slightly protruding; flesh dark red, firm, core pink, partly hollow; flavor mild sub-acid; ripens in midseason. The berries secured from the first generation of the cross of these varieties were angular to oblong, slightly conic; of medium size, with hollow pink cores; the external color, pale red; internal color, red; flavor, sub-acid; seeds numerous, green, protruding; quality, fair; ripens in midseason; flowers bisexual, there being about two staminates to one pistillate in 68 plants under observation.

The Marshall characters, such as size, pink hollow cores, long fruit clusters and, to a certain extent, perfect flower structures, were found in the first generation. On the other hand, the Haverland characteristics that were inherited were the scarlet color of the berry, prominent, protruding seeds, reflexed calyx and necked berries that were oblong-conic. The time of ripening was midseason as is the case in both of the parents. The berries of the second generation were few in number and poor in quality and no reliable description could be made from them.

In the third generation, the berries were round, small, dark red externally, pale red internally, with narrow, solid white cores; prominent, protruding seeds; flesh firm; flavor sub-acid; quality good; and season, medium. The fruit stalks were stout, holding the berries aloof from the ground. The shape, seed characters, quality and stalks were like those of Marshall, while the solid core, pale red color of flesh and the scarcity of runners were those pertaining to Haverland. The firmness of flesh, midseason of ripening, and sub-acid flavor were common to both Haverland and Marshall. With the distribution of variety characters as noted herewith, the progeny constitutes quite a departure from either parent, but is in some respects superior to either, more especially the Haverland, for the imperfection of flower was overcome and stout flower stalks were substituted for weak ones. The hollow core and the discolored and depressed calices of the Marshall did not appear in the new plants. The foliage of the progeny was abundant and spreading, with leaves of large size. The fruit stalks averaged three inches in length, were slender, often single but sometimes branched. The plants were productive. The season of ripening was medium early and the quality of the berries very good.

*Haverland crossed with Dicky.*—The product of this cross gave fruits which in the first generation were in some particulars like one parent and in some respects like the other. The Dicky attributes were exhibited in the round-conic shape of the fruit which was smooth, firm and often necked and in the capacity to form many runners. The progeny took after their maternal parent, the Haverland, in producing slender fruit stalk that were too weak to support the fruit, in ripening in midseason and in bearing good quality berries which possessed numerous small brown protruding seeds.

The berries of the second generation were round-conic, slightly necked, small to medium in size, dark red externally and light red internally. The flavor was sweet, the seeds numerous, small and protruding, the texture firm, quality excellent, season medium. The calyx was small, the stem slender, and runners numerous. The attributes of Dicky were shown in the round-conic shape of the berry and in the capacity to form numerous runners. The firm flesh and sub-acid flavor were attributes common to both varieties. In the main, the Haverland characteristics persisted, for the new forms had slender fruit stalks, the seeds were small, brown, numerous and protruding.

In reproduction by seed there were in the first generation 96 perfect flowered plants and 92 imperfect ones. In the second generation, there were 185 perfect and 12 imperfect flowered plants. It is thus seen that the Dicky flower type was inbred into forms that possessed to a marked degree the Haverland characteristics. The new plants produced handsome berries of excellent quality. The plants were of strong constitution, moderately productive and healthy. The less desirable features of this strain were the short leaf stalks and the short drooping fruit stalks, characteristic defects that are common to most varieties of strawberries. Thus it seems that either a new Haverland was developed or a new Dicky created.

In thus reciting the distinguishing features of the new forms and comparing them with their parents, the main purpose is to set forth the effects of intercrossing these staminate and pistillate varieties on the general composition of characters in the new strains. The foregoing descriptive analyses of the physical and functional attributes show that despite the contrast in several characters of the varieties mated with Haverland, the new forms, aside from certain unimportant details, show a distinct persistence of the Haverland characteristics. The flower structures in a considerable number of the progeny are not like Haverland, but in most of the other attributes the plants are still Haverlands. It appears to be easier to inbreed the missing or the impotent sex than to introduce or eliminate other attributes of the male parents.

### SAMPLE CROSSED WITH EXCELSIOR AND GANDY

*Sample crossed with Excelsior.*—Sample which is a pistillate variety is distinguished as follows: Berry large, round-conic, dark crimson; flesh, dark red, firm; core, hollow; flavor, sub-acid; quality, good; runners numerous; calyx spreading; seeds prominent, sunken, red; fruit stalks, single, drooping, about two inches long; season medium to late. Excelsior, a staminate, has the following characteristics: Berry medium size, round-conic, dark crimson; flowers semi-perfect; calyx and corolla small, latter adherent; seeds, brown, depressed; core, dark red, solid; flavor, very acid; fruit stalks, short, procumbent; runners, numerous; season, very early.

The fruits of the first generation were irregular round-conic in shape; size, medium; core, hollow, pink; color, dark red; flavor, subacid, almost sweet; ripe in midseason; seeds, medium size, depressed; fruit stalk, slender; runners numerous. This generation was like Excelsior in only two respects, namely, size of berry, which was medium, and size of calyx, which was small. It was distinctly like Sample in only two respects, namely, the flavor which was sub-acid and the seed which was red. In common with both parent varieties the seeds were depressed, the shape was round-conic and the runners were numerous and slender. In the first generation there were 205 bisexual and 128 unisexual plants.

*Sample crossed with Gandy.*—The variety Gandy is known by the following description: Berry, large, uniform, roundish to round-conic; rich, dark, scarlet; calyx, large; seeds numerous, slightly protruding; flesh, red, firm; core, hollow; flavor, sub-acid; runners, moderate; season, late.

Sample crossed with Gandy gave in the first generation plants with the following characteristics: Berry, round-conic, large; dark red; core, hollow, narrow, red; calyx, large; flower stem erect, large; flesh firm, dull red inside; seeds numerous, protruding; flavor, acid; ripe in midseason; runners, moderate. The flowers showed segregation as to sex, there being 88 bisexual to 75 unisexual in a total of 163 plants under observation. The plants of the second and third generation differed mainly from those of the first generation in producing oblong-conic rather than round-conic berries, in having the seeds depressed rather than protruding, in being of a more mild flavor, sub-acid rather than acid. The fruit was very attractive and the quality excellent. The flowers in both the second and third generations were all staminate.

In view of the fact that such characters as shape of berry, color of fruit, firmness of flesh, and sub-acidity of flavor were common to both Sample and Gandy, there was little left for comparison with either parents, or as distinctive of either variety. However, the large size of berry was easily attributable to Sample, while the calyx, flower stem and runner formation were like Gandy, as were also many of the flowers. In fact, the new variety would readily pass either for Gandy or a sexually reconstituted Sample.

In all cases the plants were very vigorous, the foliage large, coarse, and free from rust. The leaves were light green, borne on short stalks a little over two inches in length. The fruit stalks were slender, erect, unbranched, measuring about three inches in length. The blossoms came early. The fruit was judged as very good and superior to either Sample or Gandy.

### TRANSMISSION OF STRAWBERRY CHARACTERISTICS

Many structural characters and some functional attributes of the strawberry seem to pass through several generations without much change. They seem to be transmissible. It has been possible to trace backward through several generations some of the structural features such as flavor of berry, position of seeds, and nature of the core of the berry and in breeding strawberries to follow these same characteristics forward in the progeny. The extent to which it is possible to connect such characters through several generations depends upon how complete and precise were the descriptions of the original varieties and upon the number of generations that have been secured by crossing. In order to show the behavior and the recurrence of some of these attributes, several instances will be cited from our records.

*Season of ripening.*—The season of ripening of the different varieties seems to follow a fairly definite order in accordance with varietal inheritance. Late maturing varieties appear to have come from late maturing parents and similarly early ones from early parents. The season of ripening of Dunlap, which is a midseason variety, can be traced backward among its predecessors to the second generation, beyond which the records are not definite. Haverland, a midseason variety, resembles its parents, the Crescent and Sharpless, in this respect. Warfield, an early variety, was derived from early ripening predecessors. Its supposed immediate parents, Crescent and Wilson, were early to midseason, and the parents of Wilson, Hovey, Keens' Seedling and Black Prince were also early or early to medium. Gandy, a late variety, has for its parents Jersey Queen and Glendale, which were both late ripening varieties.

What is the season of the new forms when early and late-season parents are used in crossing? Warfield, an early, and Gandy, a late variety, were crossed and note taken of the progeny. The first generation were midseason forms, as were nearly all of the second and practically all of the third. Warfield was also bred by Marshall, a midseason variety, and midseason forms were secured. When Sample, a late variety, and Excelsior, a midseason one, were bred the progeny were either medium or medium-late in ripening; likewise Sample, when bred with Marshall, which is medium, produced midseason-late offspring. With respect to crosses between other varieties, it was observed that the parents were for the most part midseason in maturing fruits and that the offspring of these were mostly midseason in ripening.

These observations seem to show that where the seasonal contrast among parents is quite sharp, the breeding of early and late varieties yields progeny which seasonally are located intermediately between their parents; and that even when the contrast in parents as to season is not great, still are the results likely to be intermediate, although gradations in the direction of the season of the one or the other parent may be expected. The seasoning of ripening of a given variety can be predicted with a considerable degree of accuracy if the ripening seasons of its parents and grandparents are definitely known.

*Flavor.*—How does the flavor factor behave among crossed varieties? The acid flavor of Warfield can be traced back not only to its immediate parents but to its supposed grandparents. Its acidity seems to be a line character. Both Golden Gate and its reputed mother, Marshall, are sub-acid in flavor. When Warfield (acid) was crossed either with Golden Gate, Dicky or Barrymore (all sub-acid), the resulting plants produced sub-acid berries. When Sample (sub-acid) was crossed with Gandy (sub-acid, with sub-acid progenitors), the resulting plants produced acid berries in the first generation but sub-acid ones in the second and third generations. When Sample (sub-acid) was crossed with Excelsior (acid, derived from acid-flavored parents—Wilson and Hoffman), only sub-acid offspring were secured even unto the third generation. Again when Sample (sub-acid) was crossed with Longfellow (sub-acid) the same degree of acidity appeared in the offspring even unto the third generation. Haverland—which is the sub-acid, and came precisely by it, for its pistillate parent, Crescent, was acid—when bred with Golden Gate—which is mildly sub-acid and rightly so, for its mother, Marshall, was only mildly sub-acid or almost sweet—yielded plants that bore almost sweet berries. When Haverland (sub-acid) was crossed with Dicky (sub-acid with sub-acid parents, Marshall and Sample), nothing but sub-acid berries were secured in the progeny for at least three generations. Cardinal is an acid berry and its immediate parent, Warfield, is also acid. When Cardinal was crossed with Longfellow (sub-acid), nothing but sub-acid berries were secured from the resulting plants. When Cardinal (acid) was crossed with Excelsior (acid), the offspring bore acid berries.

It is significant to note that the degree of acid flavor seemed to be a constant factor and was passed on to succeeding plants, apparently unchanged. When acid and sub-acid flavors were mixed in breeding, the offspring resembled the milder parent in flavor. Likewise, when sweet and sub-acid flavors were mixed, the milder flavor became the prevailing one. With a narrow range of flavors, such as obtained in these trials, it appears that when different acid qualities are mixed in breeding work intermediate flavors generally result, which tend more nearly to resemble the parent with the milder flavor.

*Seed placement.*—Seeds add beauty and attractiveness to strawberries. If large and protruding, they tend to enhance shipping qualities since they furnish some degree of mechanical protection to the fruit. With respect to position, the seeds on strawberries may be disposed in three ways: they may be submerged in the flesh, as is the case with native Vermont berries of the species *virginiana,* or protruding, as with the Chilean or, in still other cases, even or flush with the surface of the berry, which is the case with some of the direct descendants of the Chilean. All of these types as to position were observed among the experimental plants.

Three of the parent varieties used in the breeding work, Warfield, Gandy and Haverland, resembled the Chilean species in seed characters and placement, and four, Excelsior, Barrymore, Golden Gate and Sample, bore seeds that were depressed or sunken in the berry, as in *F. virginiana.* In the offspring resulting from these crosses, it was found that when protruding seeds occurred in both parents the offspring also possessed protruding seeds, as, for instance, when Warfield and Gandy, or Haverland and Gandy, were crossed. Moreover, when a parent with protruding seeds was crossed with one possessing depressed seeds, segregation occurred after the first generation. The first generation bore protruding seeds, whereas some plants of the second and third generations were depressed like one parent and some protruding like the other. It so happened that no crosses were made using parents in which the seeds were depressed in both cases, but the above instances show that it is possible to determine the seed position by selecting the parents and thus to secure offspring with protruding seeds.

*Core structures.*—Most varieties have a definite core structure. It may be firm and solid throughout or the tissues may cleave and break away at the center, forming a hollow space. It is rare that intermediate structures of the two types are found. The core structure of a strawberry has some economic importance. A solid core gives greater commercial value to a variety by giving a firmer berry thus enhancing its shipping resistance. Warfield which has a solid core is well known for its good shipping qualities. Moreover, berries with hollow cores are less attractive when sliced or cut open in the process of serving. The elimination of a hollow core is therefore desirable. The core structure of several varieties, as exhibited in their ancestors and their progeny, has been traced. Warfield inherits a solid red core from the Wilson and the Crescent, both of which had solid cores, but the original source in this instance of solid cores is not known. When Warfield was crossed with Gandy, which possesses a hollow core, it was found that some of the offspring had hollow cores like the male parent while others had solid cores. When Warfield was crossed with Golden Gate, which seemed to be semi-solid, solid cores resulted in the first and second generations. Warfield, crossed with Barrymore, gave a solid cored offspring, both parents possessing solid cores.

Sample has a hollow core, although its derivation is not known, as there is no record of core structure in Leader, its mother. Sample and Gandy were crossed and gave hollow cores, like both parents. Sample, when crossed with Excelsior, the latter having a solid core, produced offspring with hollow cores in the first and third generations but with solid centers in the second one.

Haverland has a solid pink core and its immediate parents, Crescent and Sharpless, both have solid, hard-fleshed cores. When crossed with Dicky, whose parents, Sample and Marshall, had hollow cores, there were solid cores in the first and second generations but there were many hollow ones in the third generation. Haverland crossed with Golden Gate, which is partly hollow at the center, gave hollow-cored offspring.

Core structures did not seem to follow any very definite order in transmission to new generations. Solid cores, crossed with solid ones, gave solids; solids crossed with hollows frequently, although not invariably, gave hollows, for in some cases segregation occurred. Solids crossed with intermediates gave solids in one case and hollows in another. The condition of hollowness is seldom apparent until the berries are fully ripe, so that age or ripeness of the fruit is one factor in determining its development or degree of openness. Since there probably are other factors, such as rapidity of growth, which modify core structures the study of core inheritance has given rather indefinite results. It seems doubtful, therefore, if hollowness or firmness of core is a traceable unit character.

## GENERAL CONCLUSIONS.

The employment of diverse soil types and of variable amounts of commercial fertilizer as well as aerial fertilization with $CO_2$, failed to modify the sexual condition of the plants, thus indicating that sterility of unisexual forms is an innate characteristic of the plant itself and that it is not due to or materially if at all affected by the character of the soil or the nature of the fertilization.

One indication that unisexuality is hereditary is that nearly all of the pistillate varieties whose histories are definitely known were found to be of partial pistillate parentage. Furthermore, some of the important pistillate varieties have given rise to a large number of pistillate offspring. Incidental observations on the behavior of sex where breeding was done for other purposes showed a tendency toward segregation of sexes.

The results of the pollination experiments also indicate that the sexual nature of the strawberry is hereditary, since in both the open and self-pollination trials with perfect varieties the progeny were nearly all perfect, whereas in the open-pollination of imperfect varieties only about half of the progeny were perfect. Furthermore, imperfect varieties crossed with perfect ones resulted in about an equal number of perfect and imperfect offspring. Back crosses of some of the latter progeny with their perfect parents showed the same general trend as in the cross-pollination experiments.

In a preliminary study of inheritance, using the descriptions of American varieties of strawberries compiled by Fletcher (9), it was found that while some correlation existed between the characteristics of the parents and the offspring, there was a noticeable "splitting up" of the factors involved, thus indicating the hybrid nature of the American varieties of strawberries.

The observations which were made at this Station of the progeny resulting from the breeding of perfect with imperfect varieties show that it is possible in some cases by careful selection of a similar staminate plant to introduce the missing sex into an imperfect variety without materially changing its other characteristics. This is especially true when a perfect variety which is quite similar to the imperfect parent is used in the cross, although even in certain cases where there were contrasting variety characters those of the pistillate variety still seemed to predominate.

Sterility in the strawberry, as now understood, appears to be largely a matter of sex inheritance. It seems very probable that most varieties of strawberry are of hybrid origin. If one accepts the likely theory that the two species, *F. chiloensis* and *F. virginiana,* are the parents of the first cultivated varieties and that these first ones are the "Pines," it then becomes possible to trace many present day forms back to the